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MEASUREMENT OF ENVIRONMENTAL RADIOACTIVITY WITH BASIC COUNTING EQUIPMENT

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In June 1959 the Biology Department of Bowling Green State University received a grant from the Atomic Energy Commission (Grant No. BM-66-59) to purchase equipment for a radiobiology laboratory. The grant was obtained for educational purposes and the proposal specified that the equipment would be devoted primarily to class use. Some of the work reported below, however, was subsidized by a research contract with the Atomic Energy Commission AT(11-1)-536.

The following list of equipment was purchased: three basic decade scalers equipped with lead shielded manual sample changers, halogen-quenched end-window Geiger-Muller tubes and preset timers; one amplifier type decade scaler equipped with a gas flow counting chamber, a cylinder of Q-gas and pressure reducing valve; one organic-quenched end-window G-M Tube; one portable G-M counter; a source kit; and a set of absorbers.

The equipment was supplied with instructions for assembly and operation. It was assembled by members of the biology department and every item was in operation within a few days after its arrival.

In utilizing this equipment we have introduced exercises in radiobiology into existing courses; for example, the general physiology course introduced an exercise in measurement of photosynthesis using C^{14}. The bacteriology course introduced an exercise comparing C^{14} uptake from $NaHCO_3$ solution by yeast cells in presence and absence of glucose. The ecology course introduced an exercise measuring the level of gross beta radioactivity in ash from natural materials. In the general biology course a lecture-demonstration, using the portable G-M counter, was introduced. The research techniques course (graduate students) included laboratory work with these instruments, and a few students registered for special problems utilizing them. During the first 9 months, over 60 students gained experience in the techniques and theory of utilizing radioactive isotopes. This number does not include the students exposed to the lecture-demonstration in general biology. The equipment is installed in a room set aside for this purpose and classes using the room are scheduled in advance to avoid conflicts.

A radiobiology workshop has been scheduled for the summer sessions. This is the only new course that has been added to the curriculum. It provides a study of the fundamentals of radiochemistry, the techniques of measuring radioactivity and of using radioactive isotopes in biological experiments.

Although the instruments purchased were well supplied with instruction manuals, these provided no information as to the efficiency of the instruments for different radioactive elements. The efficiency of an instrument is, of course, profoundly influenced by the shape and thickness of the sample, and the distance of the sample from the window of the G-M tube, but a table of efficiencies for specific substances of given sample thickness and distance from the tube will provide a valuable reference source for comparison of different instruments. In

table 1 such data are provided. Table 1 shows that the beta radiation from potassium, which has an energy of about 1.3 MEV, is detected with an efficiency of about 4 to 7 percent with the halogen-quenched G–M tube, if it is within about 1 cm of the end of the tube, and a sample of 1 g or less is contained in a planchet of 7 cm^2 area. Potassium contains naturally radioactive K^{40} in such concentration that one gram of potassium undergoes 1660 disintegrations per minute ($0.75 \times 10^{-3} \mu c$). It is a most convenient source to use for instrument calibration. It is also revealing for the student to compute the number of K^{40} disintegrations per minute in the adult body knowing that the normal potassium concentration is about 2 g/kg of body weight.

The windowless gas flow counter detects about 33 percent of the K^{40} disintegrations. The weaker C^{14} radiations, however, (energy of about 0.14 MEV; Comar, 1955) are detected by the gas flow counter with an efficiency of only 5 percent. The halogen-quenched end-window tubes measure only 0.4 percent of the radiations emitted by C^{14}. In spite of the low efficiency of the end-window tubes for C^{14}, we have used them successfully for experiments employing this isotope. For example, if 25 ml of pond water are labelled with 0.25 μc of $NaC^{14}O_3$ and exposed to natural light for 6 hr, then filtered through a millipore filter, the activity on the filter will usually register 50 or more counts per minute on an instrument having an efficiency factor of 0.004. A five-minute count of such a filter

TABLE 1

Efficiency of various instruments under specified conditions

Radioactive substance	Type of tube	Distance from tube (cm)	Sample* weight (g)	Efficiency
KCl	Halogen Quenched end window, 1.4 mg/cm^2	0.4	1.02	0.051
"	"	0.4	0.40	0.065
"	"	0.4	0.20	0.070
"	"	1.2	0.87	0.043
"	Gas flow†	windowless	0.57	0.33
C^{14}	Halogen Quenched end window, 1.4 mg/cm^2	0.9	0.001	0.004
"	Gas flow†	windowless	0.001	0.05

*The sample was distributed over an area of about 7 cm^2.

†The gas flow counter (Nuclear Chicago D47) was attached to the amplifier type scaler (Nuclear Chicago 186A), the others were attached to basic scalers (Nuclear Chicago 186).

will measure the activity with a certainty of about 85 percent. This is similar to the reproducibility of duplicate samples; hence, there is no virtue in prolonging the counting time of individual samples.

Before we obtained the equipment listed above, the physics department of Bowling Green State University permitted us to use its basic scaler equipped with a halogen-quenched end-window G–M counter. Karl Schurr, a graduate student in biology, collected specimens of various plants and animals, dried and ashed them, and measured radioactivity of ash samples. Some of the data from his Master's Thesis were used to compile table 2. The observed counts per gram per minute are recorded. The disintegrations per gram per minute were computed using the efficiency factor for K^{40} (0.0038) and the $\mu\mu c$ per gram were computed using the relationship 1 $\mu\mu c = 2.22$ disintegrations per minute. Leaves from terrestrial plants showed the highest activities; leaves from aquatic plants showed

less; and ash from most animal tissues yielded counts hardly distinguishable from the background count of the instrument (13 counts/min).

The high values observed for Sycamore and Willow leaves are higher than the highest average values reported by laboratories using more sensitive instruments. Thus, Nehemias and Whipple (1955) found grass leaves to yield the highest gross beta counts of any organisms they studied. The average concentration observed

TABLE 2

Radioactivity of ash from plants and animals (1957)

Material	counts/g/min	disintegrations/g/min	μμc/g
Terrestrial plants			
Sycamore leaves	114	3000	1350
" fruits	15	390	175
" buds	14	370	166
Mixed wood ashes (fireplace)	14	370	166
Willow leaves	101	2660	1200
Hackberry leaves	57	1500	675
Trembling Aspen leaves	50	1310	592
Aquatic plants			
Potamogeton leaves	27	670	319
Vallisneria leaves	28	726	327
Rhizoclonium	20	526	236
Cladophora	11	290	130
Animal			
Duck liver (Scaup)	19	500	215
Mouse legs	8	210	95
Mollusc flesh	8	210	95
Earthworm	2	53	24
Blue gill	1	26	12
Isopods	0	0	0
Snails	0	0	0

TABLE 3

Radioactivity and potassium content of ash from deciduous tree leaves (1958)

Species	Radioactivity (disintegrations/g/min)	Potassium content (%)
Cottonwood, *Populus deltoides*	1400	4.9
Basswood, *Tilia americana*	625	8.6
White Birch, *Betula papyrifera*	3050	11.4
White Oak, *Quercus alba*	2200	6.9
Sycamore, *Platanus occidentalis*	900	5.3
American Elm, *Ulmus americana*	1800	10.6
Catalpa, *C. bignoniodes*	2250	8.7
Maple, *Acer saccharinum*	3200	8.2
Ash, *Fraxinus americana*	3170	10.0
Average	2066	8.3

in their grass samples was 25 μμc per g wet weight; this amounts to about 250 μμc per g of ash, because 10 g of grass leaves yielded about 1 g of ash. During 1958 we made further analyses of ash from leaves of deciduous trees. Ralph Sechriest, a graduate student, did this work. Because potassium is an important component of plant ash, subsamples of ash were sent to the Brookside Research Lab.,

Inc., New Knoxville, Ohio, for quantitative spectrophometric analysis of potassium content. The observed radioactivity and potassium content of ash of nine species are presented in table 3. The average radioactivity was 2066 disintegrations/g/min and the average potassium content was 8.3 percent. Hence, the observed potassium content could account for only 200 disintegrations/g/min or about 10 percent of the observed radioactivity. A smaller group of samples analyzed for potassium in 1957 yielded values similar to those of table 3.

During the summer and fall of 1959 a broader survey of terrestrial plant leaves was made. Many more species were collected than previously, and collections were made at intervals during the season to learn whether the radioactivity of the ash increased as the season progressed. In table 4 the average levels of radioactivity observed during 1959 are compared with the average values from 1958 and 1957. The samples collected in June yielded a slightly higher average value of radioactivity than the July and September samples, but the differences are not statistically significant. The significant feature of this study was that the level of radioactivity did not increase as the season progressed.

TABLE 4

Average radioactivity of ash from terrestrial plant leaves collected at various times

Time	Fall '57	Fall '58	June '59	July '59	Sept. '59
Gross β disintegrations/g/min	2192	2066	1260	1060	1120
$\mu\mu$c/g	985	930	568	477	505

TABLE 5

Average radioactivity of ash from old cornstalks compared with cornstalks and corn leaves grown during summer of 1959

	Old Cornstalks	1959 Stalks	1959 Leaves
disintegrations/g/min	456	550	1490
$\mu\mu$c/g	205	248	670

Each value is the average of 8 or more samples. The difference between stalk and leaves is statistically significant beyond the 0.01 level. These data were obtained with the gas flow counter having an efficiency of 33 percent for K^{40}. The disintegrations/g/min were computed by multiplying counts/g/min by 3. Samples of about 0.1 g in planchets having an area of 7 cm^2 were used.

The 1959 average values were distinctly lower than those observed in 1958 and 1957, and a sample of the willow ash which had been saved from the 1957 collection when counted in 1959 yielded only 1100 disintegrations/g/min. These data suggest that a considerable fraction of the radioactivity detected in these ash samples represents debris from weapons testing and that the reduced levels in 1959 reflect decay of short-lived components detected in 1957 and 1958. The absence of a detectable increase in level of radioactivity during the 1959 season suggests that very little radioactivity was absorbed by the leaves from rain during that season; however, the summer was unusually dry.

During the winter of 1959–60 a collection of cornstalks and leaves from a field near Bowling Green was studied and compared with a sample of old cornstalks collected from my barn at Put-in-Bay, Ohio. The old cornstalks were present in the barn when I purchased it in 1948; so, they had been stored for more than 11 years. The radioactivity of ash from these samples is presented in table 5.

The 1959 cornstalks revealed a level of radioactivity only 20 percent above that of the old cornstalks. But the 1959 leaves revealed a level about 3 times higher than the stalks. The simplest explanation for the higher radioactivity of these leaves is that they absorbed it from atomic debris in rain that washed over them. If this excess radioactivity were absorbed from the soil it is difficult to understand why it would be deposited preferentially in the leaves, and if the minerals absorbed from soil in 1959 included considerably larger amounts of radioactive atoms than were absorbed by the old stalks, one would expect a larger difference between the old corn stalks and those of 1959.

One additional study was carried out with the ash from cornstalks and leaves: a number of discs were cut from an aluminum sheet, measured, weighed, and their weights per cm² computed. These were used as absorbers and the transmission through various thicknesses was measured (Harley and Hallden, 1959). In figure 1 the transmission data for radiation from corn leaf ash are presented. Similar data from a sample of KCl were used to establish the line so labelled. In

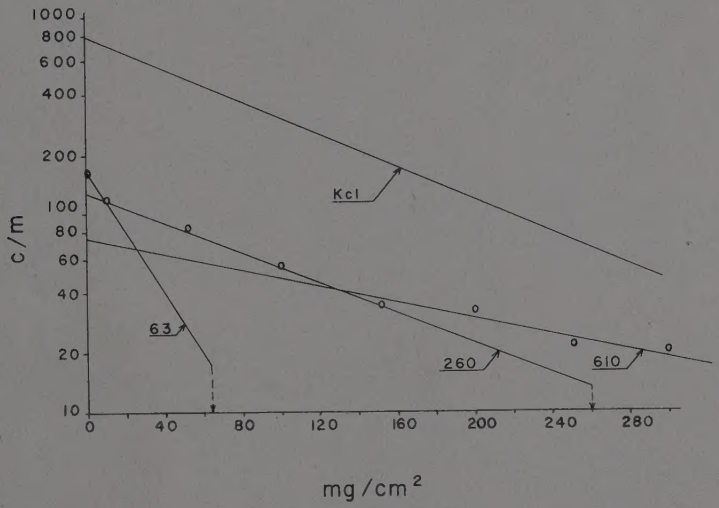

FIGURE 1. Semi-log plot of counts per minute versus absorber thickness (mg/cm²). Lower plot represents ash from corn leaves collected December 1959. Numbers indicate $t_{0.1}$ values.

analyzing such data it is convenient to draw a line through a set of data and compute the weight per cm² required to reduce the transmission to one-tenth of the initial intensity (1 cycle on the logarithmic scale). This parameter, which we will call $t_{0.1}$, is directly proportional to the energy of the beta radiation emitted by the source. Thus, KCl with an energy of about 1.3 MEV has a $t_{0.1}$ value of about 250 mg/cm², and C^{14} with an energy of 0.14 MEV has a $t_{0.1}$ value of 28 mg/cm². In the ash from corn leaves there seem to be 3 distinct components: a low energy component having a $t_{0.1}$ value of about 63 mg/cm², an intermediate component whose $t_{0.1}$ value is closely similar to that of K^{40}, and a high energy component whose $t_{0.1}$ value is about 610 mg/cm². Similar analyses of the ash from cornstalks, old and new, revealed only a single component, approximating the line of intermediate slope in figure 1. It seems likely that the low energy component represents a mixture of soft beta emitters. $Cerium^{144}$, a beta emitter with energies of

0.3, 0.2 MEV and Zirconium^{95} (β, 0.4 MEV) are prominent products of weapons tests (Van Dilla, 1960) and may be important in this portion of the curve. The intermediate slope is certainly influenced by natural K^{40}, but this line also may represent a mixture for there are radioisotopes of energies 1 to 2 MEV in weapons debris which could not be distinguished from K^{40} in this portion of the curve. The high energy portion of the curve may be influenced by Rhodium^{106}, the daughter of Ruthenium^{106}, which is also abundant in weapons debris. Rhodium has a half life of only 30 sec so the disintegration Ru^{106} (β, 0.04 MEV) would be quickly followed by the decay of Rh^{106} (β, 3.5 MEV). The daughter of Cerium^{144}, Praseodymium^{144}, also emits a strong beta (3.0 MEV) and Strontium^{90} (β, 0.5 MEV) has a daughter Yttrium^{90} whose beta energy of 2.2 MEV would place it on this portion of the curve.

An analysis of the kind portrayed in figure 1 will not separate the individual elements in the complex mixture of substances likely to be present in fallout from weapons tests, but it does provide information about the variety of beta energy levels present in the mixture; and the contrast between stalks and leaves suggests that the leaves collect fallout to a much greater extent than do the stalks. The similarity between the radioactivity of ash from old and new cornstalks suggests that most of this radioactivity is contributed by naturally radioactive elements, with K^{40} predominating.

The data presented above demonstrate that radioactivity in ash from natural materials is sufficiently high to be measured with equipment (basic scaler and halogen-quenched end-window G–M tube) now becoming available to many colleges through educational grants from the Atomic Energy Commission. Although measurements of radioactivity in the environment are being made more accurately by laboratories equipped with more sensitive (and expensive) equipment (Nehemias and Whipple, 1960; Setter and Straub, 1958), a student's understanding of the problem is improved by carrying out studies like those described above.

SUMMARY

Instruments purchased with an educational grant from the AEC measured the radioactivity of ash from materials collected in nature. Ash from plant leaves showed levels of about 1000 $\mu\mu c/g$ during 1957 and 1958. Leaves collected in 1959 showed levels only one-half so high. Ash from corn stalks was only one-third as radioactive as that from leaves. Surveys of this kind can be carried out by undergraduate students.

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HISTOCHEMICAL LOCALIZATION OF PHOSPHATASES IN THE STABLE FLY, *STOMOXYS CALCITRANS* (L.), USING NAPHTHOL AS-PHOSPHATE[1]

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INTRODUCTION

The detection of phosphatases in insects began about 20 years back when Nakamura (1940) localized alkaline phosphatase in the silk gland of *Bombyx*. Later Krugalis (1945) demonstrated alkaline phosphatase in the chromosomes of the salivary glands of *Drosophila melanogaster* larvae, and Bradfield (1946) reported the presence of the same enzyme in insect cells which synthesize fibrous proteins. Day (1949), using Gomori's technique, studied the distribution of alkaline phosphatase in insect tissues. Yao (1950a, b) demonstrated phosphatases in various tissues of *Drosophila melanogaster* during embryonic and postembryonic development. Belden (1958), using Gomori's method, made a detailed study of histochemical localization of acid and alkaline phosphatases in adult males of DDT-resistant and DDT-susceptible strains of the house fly, *Musca domestica*. Salkeld (1959), using naphthol AS-acetate as a substrate found a pronounced nonspecific esterase activity in the posterior lobe of salivary glands and the fore part of the midgut of the large milkweed bug, *Oncopeltus fasciatus*, Dall. Recently, Burstone (1958c) reported a new technique, in which naphthol AS-phosphates were used to get precise localization of phosphatases in mammalian tissues. He stated that this technique has certain advantages over other histochemical methods in that: (a) naphthol AS-phosphates are among the most substantive and insoluble naphthols; (b) diazonium salts couple rapidly with enzymatically released free naphthol from the substrate and form a dye product of homogeneous (non-crystaline) structure; and (c) the dye-stuff produced is very insoluble and remains at the site of its formation. In view of the advantages of Burstone's technique, it was selected for the present investigation of acid and alkaline phosphatases in the stable fly, *Stomoxys calcitrans* (L.).

MATERIALS AND METHODS

Live three-day-old adult stable flies were chilled for 30 minutes at a temperature of −15°C to avoid serious postmortem distortion of phosphatases (Gomori, 1952). Next, the tissues were fixed and dehydrated in a mixture of equal volumes of cold acetone and absolute alcohol for twelve hours. They were transferred to fresh fixative at 12, 24, and 36 hours. After 48 hours, the tissues were washed with cold chloroform. Ether was avoided because it was found to interfere with sharp localization of phsophatases in stable fly tissues. The embedding was done in paraffin wax under reduced pressure and the tissue sections were cut at 9 microns.

The sections were dewaxed in cold xylene for 30 minutes and were then hydrated by passing them successively through alcohols of 100, 90, 75, and 35 percent. The sections were exposed for two minutes in each grade of alcohol. Finally, sections were immersed in distilled water for one minute, then transferred to the incubation mixture and held at a water bath temperature of 38°C for 30 minutes to two hours.

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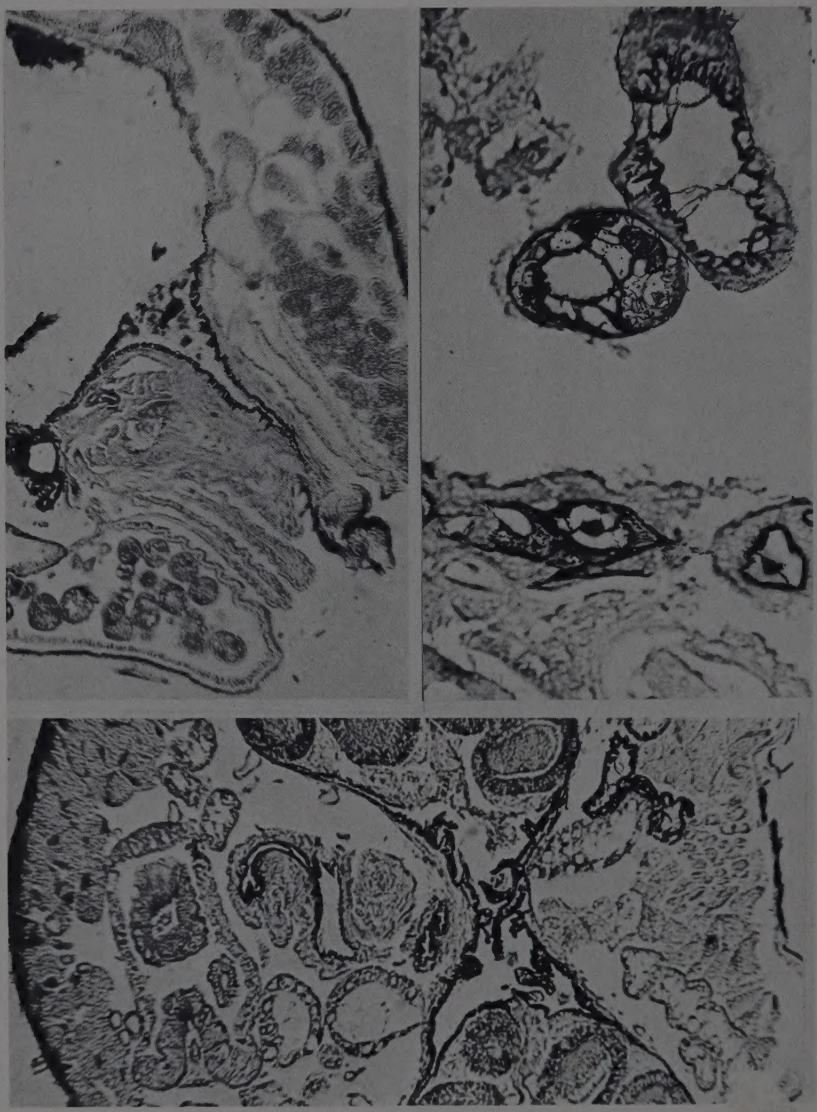

FIGURE 1. (Upper left) Longitudinal section of hindgut. Rectal contents and the epitae. m of the posterior part of the rectum showing acid phosphatase activity.

FIGURE 2. (Upper right) Cross section of Malpighian tubules, showing localization of acid phosphatase in the protoplasm of the cell.

FIGURE 3. (Bottom) Cross section of female stable fly abdomen. Acid phosphatase activity is present in the cytoplasm and nuclei of the epithelial cells of oviduct and uterine glands.

The incubation mixtures were prepared as follows (Burstone, 1958c): Five mg of substrate (Naphthol AS–BI phosphate for acid phosphatase, and naphthol AS–MX phosphate for alkaline phosphatase) were dissolved in 0.25 ml N, N-dimethylformamide followed by 25 ml distilled water and 25 ml of buffer (0.2 M acetate of pH 5.2 for acid phosphatase, and 0.2 M trishydroxymethylaminomethane buffer of pH 8.3 for alkaline phosphatase). Then 30 mg of Red Violet LB salt for acid phosphatase or of Fast Blue BBN salt for alkaline phosphatase was added. This mixture was shaken and filtered into a Coplin jar. Two drops of 10 percent $MnCl_2$ were added to the incubation mixture prepared for acid phosphatase localization.

As a result of phosphatase activity during incubation, AS-naphthol was liberated from naphthol AS–BI phosphate and naphthol AS–MX phosphate. The liberated AS-naphthol couples immediately with diazonium Red Violet LB salt, forming an insoluble red pigment in the case of acid phosphatase or with diazonium Fast Blue BBN salt, forming a blue pigment in the case of alkaline phosphatase.

After incubation, the sections showing the acid phosphastase activity were counterstained with hematoxylin and those showing alkaline phosphatase with eosin. The sections were mounted in glycerol jelly.

RESULTS

Acid and alkaline phosphatases appeared to be widely distributed in the cytoplasm and nuclei of the cells of the tissue in which they were localized. The acid phosphatase activity of the nucleus was dominant over the acid phosphatase activity in the cytoplasm, while the reverse held for alkaline phosphatase. In some tissues both acid and alkaline phosphatases were shown to be present at the same sites.

Acid phosphatase activity.—Only moderate phosphatase activity was found in the epithelium of the posterior part of the rectum (fig. 1). The distal part of the salivary gland was also a site of moderate activity. This activity was oriented in the lumenal margin of the epithelial cells of the salivary gland, and was decreasing towards the proximal part of the gland.

A distinct localization of acid phosphatase was observed in the lumenal brush border of the malpighian tubules (fig. 2). The activity was noted in both distal and proximal parts of the tubules.

Acid phosphatase was not found in the ovarian follicles of three-day-old female flies, but was widely distributed in the cytoplasm and nuclei of the epithelial cells of the oviduct and uterine glands (fig. 3). The testes were devoid of acid phosphatase activity, but testicular ducts and seminal vesicles did show activity.

Alakline phosphatase activity.—The entire midgut epithelium showed maximum activity, with the brush border of the mesenteron exhibiting a dense localization of alkaline phosphatase activity (fig. 4). A trace of alkaline phosphatase activity was noted around the base of the rectal papillae and intimal lining of the posterior part of the rectum.

Moderate activity of alkaline enzyme was observed in the proximal part of the salivary glands. The distal lobe of each salivary gland showed a strong intracellular orientation of the enzyme (fig. 5). Most of the activity was found in the lumen of the gland and the cells bordering it.

A strong alkaline phosphatase activity was noted in the brush border of the distal part of the malpighian tubules. The cytoplasm was the seat of a sharp alkaline phosphatase activity in the cells of malpighian tubules.

A marked alkaline enzyme activity was found in the cytoplasm and nuclei of the oviduct and uterine gland epithelial cells (fig. 6). Testicular ducts showed traces of alkaline phosphatase activity.

DISCUSSION

Several authors have mentioned that histochemical localization of an enzyme

depends upon the initial fixation, substrate used, product of hydrolysis, and end-product of dye pattern formed at the site of enzyme activity. Danielli (1954) summarized the factors necessary to obtain good results as: (a) solubility of the precipitated end-product due to enzymatic activity should be low; (b) an

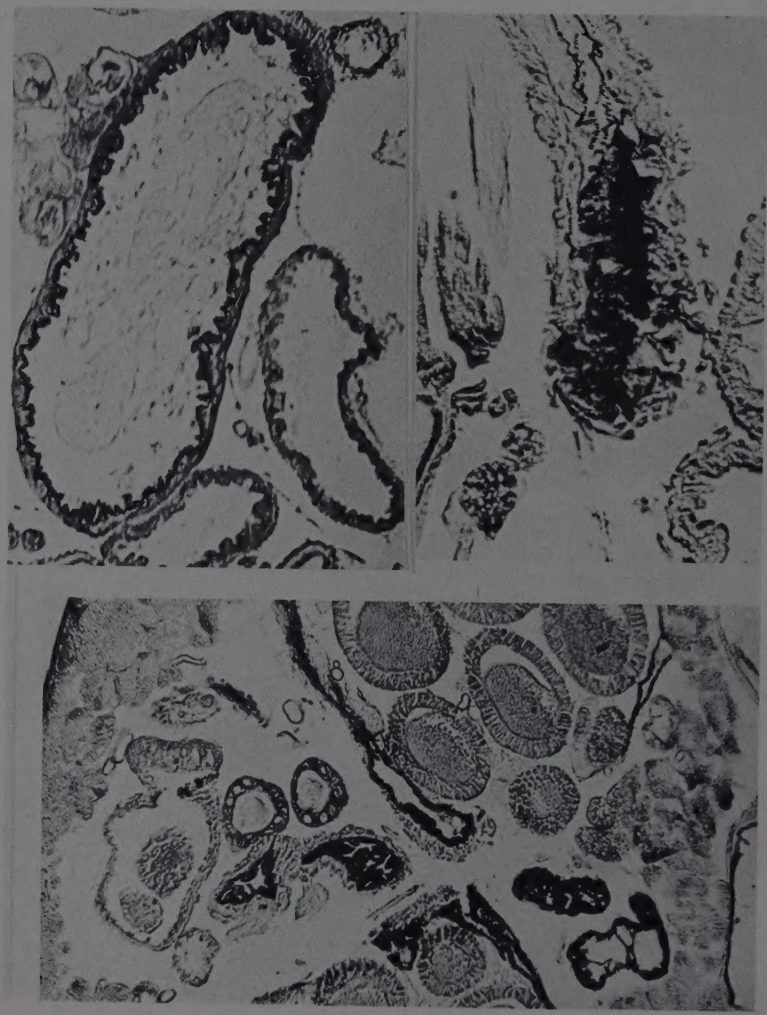

FIGURE 4. (Upper left) Longitudinal section of midgut, showing alkaline phosphatase activity in the midgut epithelium.

FIGURE 5. (Upper right) Longitudinal section of salivary gland. Most of the alkaline phosphatase activity is confined to the lumen and the cells adjacent to it.

FIGURE 6. (Bottom) Cross section of a female stable fly abdomen. Alkaline phosphatase activity is present in the cytoplasm and nuclei of the epithelial cells of oviduct and uterine glands.

abundance of precipitation nuclei (crystallization nuclei) should be present; and (c) the rate of enzymatic action should be sufficient to ensure a considerable amount of released phosphate. The first factor was satisfied when the solubility of the precipitated end-product was found almost nil at pH 5.2 and pH 8.3. The second factor was satisfied by the findings that usually all sites of the cell had high concentrations of precipitation centers. Whether our results satisfy the third factor of Danielli may be questioned, because many authors reported 65 percent loss of phosphatase activity during fixation, dehydration and embedding. In the present investigation, acetone-fixed and paraffin-embedded tissues have been used, although it has been reported (Eränko, 1951; and Samorajski, 1960) that cold acetone fixation is destructive to acid phosphatase. Seligman (1951) reported the use of cold neutral formalin fixation to overcome this difficulty. He showed that with cold formalin fixation acid phosphatase activity was preserved somewhat better, but that alkaline phosphatase was greatly reduced. Since the biochemical tests had shown a high concentration of acid phosphatase and a low concentration of alkaline phosphatase (Ashrafi, 1960), the method of fixation selected was that which favored the alkaline phosphatase. Therefore, acetone-fixation and paraffin-embedding may limit the present azo-dye procedure due to the possibility of negative results at the site of weak enzyme activity. However, this procedure gave an accurate and sharp localization at the sites of strong enzyme activity. Therefore, Danielli's third factor was at least satisfied in the regions where sufficient enzyme activity remained in the sections after preparation.

Acid phosphatase activity was not detected in the stomodaeal region. Only moderate activity was noted in the posterior rectal part of the digestive system. A weak acid phosphatase activity was localized in the salivary glands of the stable fly. Prior to this work only Belden (1958) reported acid phosphatase activity in insect salivary glands. A distinct acid phosphatase activity was found in the stable fly malpighian tubules. Similar findings were reported by Drilhon and Busnel (1945), Yao (1950), and Belden (1958) in other insects. Testes of the three-day-old adult stable flies were devoid of acid phosphatase activity, but testicular ducts and seminal vesicles showed weak acid phosphatase activity. The activity was also localized in oviducts and uterine glands. Belden reported the presence of acid phosphatase activity in the testicular ducts of the house fly.

Alkaline phosphatase activity was localized in the entire midgut, and the foremidgut showed the maximum activity. Waterhouse and Stay (1955) reported alkaline phosphatase activity in the anterior and posterior midgut of *Lucilia cuprina* (Wied.) larvae, and showed the storage of glycogen and lipids in the same region. Traces of alkaline phosphatase were also noted around the base of the rectal papillae and intimal lining of the posterior rectum of the stable fly. A strong alkaline phosphatase activity was noted in the distal part of the stable fly malpighian tubules. Similar observations were made by Day (1949) in *Lucilia cuprina*, Yao (1950) in *Drosophila melanogaster*, and Belden (1958) in *Musca domestica*. The sharp orientation of alkaline phosphatase was found in the lumen of the salivary gland and the cells bordering it. Krugalis (1945), Bradfield (1946), Day (1949), Yao (1950), and Belden (1958) reported strong alkaline phosphatase activity in the salivary glands of other insects. Testicular ducts, oviducts and uterine glands showed weak alkaline phosphatase activity. Similar results were reported by Day and Belden.

Acid and alkaline phosphatase activity was not detected in the tracheae, nerves, muscles, or fat bodies of the stable fly, while it was reported in certain of these tissues by Day, Yao, and Belden in the insects they studied.

SUMMARY

Acetone-fixed and paraffin-embedded sections of the adult stable fly tissues were incubated in a mixture of naphthol AS-phosphates along with diazonium salts.

Moderate acid phosphatase activity was localized in the epithelium of the posterior part of the rectum, distal part of the salivary glands, testicular ducts, and the seminal vesicles. Strong acid phosphatase activity was observed in the malpighian tubules, epithelial cells of the oviduct, and uterine glands.

Moderate alkaline phosphatase activity was shown around the base of rectal papillae, intimal lining of the posterior part of the rectum, proximal part of the salivary gland, and testicular ducts. Strong alkaline phosphatase activity was noted in the fore-midgut, distal lobes of the salivary glands, distal part of the malpighian tubules, oviducts and uterine glands. These findings were compared with the reports of others working with insect tissues.

Positive results with naphthol AS-phosphates in the presence of diazonium salts of higher coupling energy offer conclusive proof of acid and alkaline phosphatase activity at the site of dye deposition. Hence, the naphthol AS-phosphates technique of Burstone can be used to accurately localize phosphomonoesterases in insects.

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The figures were reproduced from photomicrographs made in color by The Ohio State University Department of Photography.

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NOTES AND RECORDS OF OHIO DRAGONFLIES AND DAMSELFLIES (ODONATA)†

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During the months from June to September of 1959, I was privileged to pursue a field research program on the distribution and ecology of the Odonata of Ohio. Collections were made in 68 of the state's 88 counties, with emphasis upon those counties less investigated by previous workers. In all, some 154 habitat sites were investigated. The number of sites per county averaged two, with a range of from one (24 counties) to six (2 counties). The program was designed to be broad in scope and to include as many areas as possible. Such a technique precluded concentrated effort in any one area, or even in any specific habitat. Habitat selection was dictated primarily by convenience, accessibility and, in some instances, pure happenstance. Using privately owned property involves the requesting of permission, a procedure that is often time consuming. Hence, attention was directed to those waters on state owned or state controlled land. Further, those lands with campsites were favored. Weekly collecting trips were planned so that a circuitous route would include a number of counties and, if at all possible, no backtracking over already investigated areas. Longer stretches of travel were reserved for early morning, late afternoon or evening, thus permitting the maximum number of hours for fieldwork during the late morning and afternoon when Odonata are most active. Unfortunately it was not possible to revisit areas during different parts of the season to investigate seasonal variance. Seasonal differences were nevertheless apparent, with certain species replacing others as the season progressed. Further, the month of August brought on a rather detrimental heat wave and an associated dry period. The extremely high daytime temperatures noticeably affected the activity of these insects. Lack of rainfall caused most marshy habitats to dry up. Some of these had not been without water during two previous seasons of collecting. As an example, "Specht Bog" of Carroll County was visited in early September. At this time the only water present was a drainage ditch reduced to sluggish pools. Farm ponds were likewise affected, even the larger ones showing a two-foot drop in water level.

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Previous seasonal work had concentrated upon standing-water habitats. Therefore, extra effort was devoted to stream environments. This effort was to some extent less fruitful than anticipated. Except in a few situations, investigations of lotic habitats were little rewarding. Though inexperienced, I would like to venture a hypothesis that the very widespread spring floods of 1959 perhaps so disrupted these habitats that the odonatan fauna was reduced.

A summation of the season's collecting will be made upon the basis of county records, a county record implying the collection of a species one or more times at one or more sites within a county. Tabulation was not made of the number of specimens collected or the number of times a species was collected within a county. Utilizing these criteria, 911 county records were made, 418 of which were dragonflies (Suborder Anisoptera) and 493 damselflies (Suborder Zygoptera). Of these records, 597 (279 Anisoptera and 320 Zygoptera) records are new county records, and two new state records. In addition, the summation will include

TABLE 1

Average and mean number of county records reported per species

	Anisoptera		Zygoptera		Total	
	Average	Mean	Average	Mean	Average	Mean
Total to 1960	10.3	6	17.8	13	14.0	7
Total including this summation	15	6	24.6	17	18.3	8

TABLE 2

Average number of counties reported for common (top 20%) and rare (bottom 20%) species

	Anisoptera		Zygoptera		Total	
	Common	Rare	Common	Rare	Common	Rare
Total to 1960	38.3	1.3	44.5	2.0	40.4	1.5
Total including this summation	51.0	1.4	64.9	1.8	55.8	1.5

records of Zygoptera collected during the summers of 1957 and 1958. This latter material consists of 73 county records of which 42 are not represented in the material collected during 1959. These have yielded 29 new county records. In the following summation all such records are followed by a dagger (†). Also, specimens collected by Eugene S. Morton (E.S.M.) and Timothy J. Morton (T.J.M.) at Rocky River, Cuyahoga County, included two new county records These are indicated by the appropriate initials.

Published records for Ohio indicate a total of 145 species represented by 2002 county records (1140 Anisoptera and 862 Zygoptera). The data reported here increase this total to 2630 county records (1419 Anisoptera and 1211 Zygoptera), representing an increase of 31.3 percent over previously published records. This increase affects primarily those species that may be classified as "common." The following charts clearly show that only the average number of counties per species has been affected, the mean number has been little changed. When one compares the species comprising the most common 20 percent with the 20 percent least often reported, it is apparent that many of these lesser reported species are either

extremely local in distribution or are adventitious species that only occasionally invade Ohio from neighboring ranges. Of the 18 species reported only once, 5 are reported by Homer F. Price. It is not surprising that this excellent field worker would report rare or elusive species, particularly those species frequenting larger streams. Twelve of the eighteen species have not been reported since Borror's summation in 1937.

The following records are all based upon collected specimens, sightings are not recorded in this summation. On this basis, actual collections are interpreted as superceding previously published records of sightings. Such new records are indicated by means of an asterisk (*). All specimens were identified by myself, and some identifications corroborated by Dr. Donald Borror of Ohio State University. The specimens are in my collection. The number used for each species, unless otherwise indicated, corresponds to that assigned or utilized by Borror (1937), Borror (1938), and Kormondy (1956).

FIGURE 1. Distribution of habitats at which Odonata were collected. Summer, 1959.

ASSIGNMENT OF NUMBERS TO OHIO SPECIES

In order to assign a species number to the included new addition to the Ohio list, it was necessary to review those numbers previously assigned. Borror (1937, 1938) assigned a total of 129 numbers in his original list and its supplement. In 1939 Wright reported the unique occurrence of *Argia fumipennis* Burmeister but did not assign it a number. Borror and Epstein (1942) note this, and list an overlooked record by Langlois (1932). They further assigned number 132 to

Dorocordulia libera (Selys). This assignment is interpreted by me to imply that number 130 should be considered assigned to *Argia fumipennis* Burmeister as reported by Wright 1939 and number 131 to *Coryphaeschna* sp. (probably *igens* Rambur) as reported byLanglois (1932). The following year Montgomery (1943) assigned number 133 to *Somatochlora linearis* Hagen. In 1950 Price brought the list to 138 species by the addition of five new records. Kormondy (1956) added a new record, assigning it number 139 and Price (1958) utilized the numbers 140 to 144 for five new records he recorded. However, the paper of Chamberlain and Whiting (1955) had apparently been overlooked. In it the authors record *Helocordulia uhleri* (Selys) from Hocking County, noting it to be the 139th species recorded from Ohio. It therefore seems advisable to assign the number 145 to *H. uhleri* at this time rather than to rearrange already assigned numbers. This then calls for the assignment of the number 146 to *Argia translata* Hagen reported below. One other change is suggested at this time. Borror (1937) assigned the number 92 to *Lestes disjunctus* Selys. However, Walker (1952) separated this species into two subspecies, both of which he notes (Walker, 1953) as occurring in Ohio. Price (1958) records *Lestes disjunctus australis* Walker as occurring in Ohio, and utilized the number 92. I here propose that the number 92 be reserved for *Lestes disjunctus, sensu lato* as utilized in older reports and to separate the subspecific designations as 92a *Lestes disjunctus australis* Walker and 92b *Lestes disjunctus disjunctus* Selys.

LIST OF NEW COUNTY RECORDS

9 *Gomphus exilis* Selys 1854.—**Harrison, Jefferson, Meigs, Muskingum.**

19 *Gomphus spiniceps* (Walsh) 1862.—**Shelby.**

This record is based upon one specimen taken as it patrolled an area of relatively smooth water between two sets of riffles in the Miami River at Port Jefferson, O.

22 *Gomphus villosipes* Selys 1854.—**Harrison, Licking.**

24 *Dromogomphus spinosus* Selys 1854.—**Clermont, Harrison, Jefferson, Morgan, Vinton.**

A female of this species was taken at Burr Oak Lake, Morgan County, with prey that appears to have been a teneral female of *Pachydiplax longipennis*.

26 *Lanthus albistylus* (Hagen) 1878.—**Jefferson.**

This species was last reported by Borror (1937) in which three central counties are recorded. Two males of this elusive little species were taken as they rested in the morning sunlight on small stones protruding from the shaded rocky stream below Lake Jefferson's dam. Their capture proved rather difficult. This collection also represents a new seasonal distribution. Borror (1937) gives the extreme dates as June 3 to June 17; this collection was made on **July 1.**

30 *Boyeria vinosa* (Say) 1839.—**Carroll.**

31 *Anax junius* (Drury) 1770.—**Adams, Gallia, Guernsey, Harrison, Huron, Jefferson, Madison, Mahoning, Medina, Meigs, Monroe, Morgan, Stark, Tuscarawas, Vinton*, Warren.**

32 *Anax longipes* Hagen 1861.—**Jefferson.**

The four previous reports of collection and three of sightings of this beautiful, exasperating species reflect its evasive powers rather than its great rarity. Never a common species, it nevertheless must be more common than these records indicate. I have spent many hours pursuing it in several areas, but was unsuccessful in all but this one case. This collection was achieved, not by skill, but by utilizing a 22 cal. rifle loaded with dust shot. This specimen was taken at a small, muddy, silt-bottomed pond in a strip-mine area. Another specimen was observed over a very similar pond high on a hill in Hocking County.

36 *Aeschna constricta* Say 1839.—**Carroll.**

38 *Aeshna umbrosa* Walker 1908.—**Carroll, Licking.**

In all cases of these collections the specimens were males taken as they cruised over small, shallow streams. The streams tended to be shaded, at least in part. The bottoms of these streams, however, varied from mud to gravel.

39 *Aeshna verticalis* Hagen 1861.—**Vinton.**

This collection was made from swarms of males at the headwaters of Lake Hope. They were taken for several hundreds of yards up the stream feeding into the lake as well as along the shore of its shallow upper end. This collection also constitutes a change in seasonal distribution from that reported by Price, 1950 (August 9) and Borror and Epstein, 1942 (October 6), these collections having been made on **August 5** and **6.**

139 *Macromia alleghaniensis* Williamson 1909.—**Scioto.**

Kormondy (1956) first reported this as a state record for Ohio from two males taken by the late Dr. Clarence H. Kennedy at Put-In-Bay on Lake Erie in 1934. In this report Kormondy notes that the only other record this side of the Allegheny Mountains is one from Kentucky. Thus, a record from southern Ohio is not too surprising. The collection consists of a single male taken at Roosevelt Lake. It was taken during the afternoon as it patrolled the headwater stream of the lake. The stream at this point was heavily shaded in parts, and the specimen seemingly established its path outside of these shaded areas. Kennedy's specimens bore no dates, hence the only seasonal data available are that of this specimen, **August 12.**

44 *Macromia illinoiensis* Walsh 1862.—**Medina** (T.J.M.).

This record is based upon a single male captured by Timothy J. Morton as it flew over the West Branch of the Rocky River in Medina County where it crosses Route 252. The river at this point has its typical sheet-rock bottom. The specimen did not have an apparent course but rather seemed to cruise the stream for some distance. It may be, of course, that we saw more than one specimen, but some time was spent and only this single male taken. After its capture no other was seen.

46 *Didymops transversa* (Say) 1839.—**Jefferson.**

This specimen was taken as it rested upon vegetation along the bank of the small shaded stream below the dam of Lake Jefferson. Borror (1937) gives the seasonal distribution as April 25 to June 6, therefore this record constitutes an extension for it was taken on **July 1.**

49 *Epicordulia princeps* (Hagen) 1861.—**Adams, Athens, Belmont, Brown, Champaign, Clark, Columbiana, Darke, Guernsey, Harrison, Jefferson, Lorain, Madison, Medina, Meigs, Miami, Monroe, Morgan, Muskingum, Noble, Pike, Summit, Tuscarawas, Warren, Washington.**

These records more than double those previously published for this species, it now having been collected in half of the counties. This is a common species in nature, if not in collections. Males are usually seen cruising a territory of some 20 to 30 yards in length over the water 10 to 15 feet from shore. They may, however, patrol a terrestrial domain while feeding. This species is very responsive to any movement within its sight range. If, as it flies by, one flips a pebble or any small object that will fall within sight, the adult will swiftly alter its flight to investigate this moving object. I have frequently utilized this habit to entice a specimen within reach of my net. Borror's (1937) extreme dates of June 2 to September 14 are slightly extended by a specimen collected at Granville, Licking County, on **May 28.**

50 *Tetragoneuria cynosura* (Say) 1839.—**Harrison, Jefferson, Morgan.**

53 *Nannothemis bella* Uhler 1857.—**Miami.**

This is the second collection of this dainty little species in the state, the other reported by Borror (1930) from Cedar Swamp in Champaign County. The above report is based on a collection of 10 males and 5 females taken at Silver Lake in Miami County on July 16. This small glacial-remnant lake is now a recreation area for the residents of New Carlisle, which is just across the Champaign County line to the west. The habitat and habits reported by Borror (1930) are affirmed by this collection. The complete, exhaustive survey of this small lake accentuated the fact that adults of this species are found only in low grass and then only if there is water beneath it. In one location the water was merely a thin film of seepage water, but the adults seemed bound to the area thusly defined.

54 **Perithemis tenera** (Say) 1839.—**Adams, Brown, Champaign, Clermont*, Clinton, Columbiana, Gallia, Guernsey, Hancock, Jefferson, Lorain, Medina, Meigs, Miami, Monroe, Morgan, Noble, Shelby*, Stark, Summit, Warren.**

55 *Celithemis elisa* (Hagen) 1861.—**Adams, Belmont, Gallia, Guernsey, Hardin, Henry, Huron, Meigs, Miami, Monroe, Morgan, Muskingum, Stark, Warren.**

The seasonal distribution of the species has been listed as June 6 (Borror, 1937) to August 21 (Borror, 1938). Specimens collected at Granville, Licking County, on **May 24** and May 31 extend the earlier date while the later date is extended by specimens collected at Fitchville, Huron County, on August 26 and at Springboro, Warren County, on **September 2.**

56 **Celithemis eponina** (Drury) 1773.—**Adams, Athens, Brown, Clermont*, Columbiana, Guernsey, Hamilton, Hocking, Lorain, Madison, Morgan, Scioto, Summit, Warren, Wyandot.**

The seasonal range of this species is given as June 13 (Borror, 1937) to August 21 (Borror, 1938). Collections at the Spring Valley Wildlife Area near Mt. Holly and at Springboro, both in Warren County, were made on **September 2.**

62 *Libellula cyanea* Fabricius 1775.—**Adams, Gallia, Hocking, Meigs, Monroe, Muskingum.**

These records extend the distribution of this species to 15 counties. Except for two counties, Defiance and Williams, reported by Price, the distribution of this species appears to concentrate in the southeastern unglaciated portions of the state. Further collections of this species may alter this impression. The species is nowhere widely distributed. Rather, it occurs in small numbers, generally associated with beds of cattails.

63 *Libellula incesta* Hagen 1861.—**Summit.**

In addition to the above Ohio record, this species was collected in northeastern Pennsylvania. Both habitats had extensive beds of emergent vegetation and in both cases the adults occurred only along the outer edges of those beds. Only during pursuit did they venture shoreward.

64 *Libellula luctuosa* Burmeister 1839. **Adams, Brown, Carroll, Columbiana, Gallia, Guernsey, Hamilton, Harrison, Jefferson, Lorain, Medina, Meigs, Miami*, Monroe, Morgan, Noble, Shelby, Stark*, Tuscarawas, Warren, Washington.**

A male of this ubiquitous species was taken while flying in tandem with a female of *Libellula pulchella*.

66 *Libellula pulchella* Drury 1770.—**Adams*, Brown, Columbiana, Gallia, Guernsey, Harrison, Jefferson, Mahoning*, Meigs, Miami, Monroe, Morgan, Noble, Tuscarawas, Warren.**

68 *Libellula semifasciata* Burmeister 1839.—**Licking, Stark, Trumbull, Tuscarawas.**

My first contact with this species occurred at a small meadow slough on State Route 314 just north of the Morrow-Knox County line. While spending an unsuccessful hour in pursuit, ample opportunity for study was afforded. Unlike most Anisoptera, this species gives the appearance of being almost communal while in flight. At this site a stiff breeze was blowing across the pond and the males were hovering over the vegetation on the lee side, headed into the wind. Usually they hovered in pairs or small groups. One group was made up of six specimens. And, almost like fish in a school, when one moved to a new spot, the others followed, remaining in formation. Similar behavior was subsequently observed at a swampy meadow near Granville, Licking County. This behavior seemed to be in response to a stiff wind for when the air was still only a few were in flight. Rather, they rested amidst the vegetation, most frequently six to ten in. above the water surface, thus below the top of the emergent vegetation. They most frequently chose a slanting or near horizontal perch. Other specimens were found in cattail marshes, fields some distance from water, and even in deep, damp woods.

(65) *Plathemis lydia* (Drury) 1770.—**Brown, Clermont, Gallia*, Guernsey*, Hamilton, Harrison, Jefferson, Lorain, Madison, Medina, Meigs, Miami, Monroe, Morgan, Noble, Scioto, Tuscarawas, Warren.**

This species is apparently an important pioneer species for it and *Libellula pulchella* are the commonest dragonflies found in the vicinity of newly formed waters, even those of a temporary nature. They seem to be attracted more to muddied water than to clear, matured waters. In the College Pond of Denison University, they most commonly patrol the area stirred up by inrushing surface run-off. The reported seasonal distribution of May 13 (Borror, 1937) to September 18 (Price, 1950) is extended by an almost teneral female taken at Atwood Reservoir, Delroy, Carroll County, on **September 24.**

72 *Sympetrum obtrusum* (Hagen) 1867.—**Muskingum, Summit.**

73 *Sympetrum rubicundulum* (Say) 1839.—**Brown, Carroll, Darke, Greene, Madison, Mahoning, Medina, Miami, Noble, Seneca, Trumbull, Tuscarawas, Warren, Wood.**

74 *Sympetrum semicinctum* (Say) 1839.—**Carroll, Miami.**

76 *Sympetrum vicinum* (Hagen) 1861.—**Carroll, Delaware, Greene, Lorain, Medina, Miami, Preble, Shelby, Summit, Tuscarawas, Union, Warren.**

77 *Leucorrhinia intacta* (Hagen) 1861.—**Ashtabula, Harrison, Jefferson, Knox, Morrow, Trumbull.**

This perky little spring Libellulid is a common pond and swamp inhabitant. It often rests upon floating vegetation. When a male and female couple, they seemingly seek shelter, flying into nearby vegetation where they rest, usually on a horizontal perch, and complete copulation. Such pairs are often surrounded by a swarm of males eager to interrupt. On one occasion three were found in a row resting on a floating mat of algae. The anterior male was coupled to another male which was coupled to a female. A female was observed flying alone over shallow water where it repeatedly touched the surface with the tip of the abdomen, apparently ovipositing. Borror (1937) reports the seasonal distribution of this species as May 9 to August 1. This range is slightly extended by three specimens collected at Sparta, Ohio, Morrow County, on **May 5.**

78 *Pachydiplax longipennis* (Burmeister) 1839.—**Belmont, Brown, Clermont, Columbiana, Gallia, Guernsey, Hamilton, Harrison, Jefferson, Lorain, Madison, Mahoning, Medina, Meigs, Monroe, Morgan, Noble, Summit, Trumbull*, Tuscarawas, Warren.**

79 *Erythemis simplicicollis* (Say) 1839.—**Adams, Athens, Brown, Columbiana, Darke*, Gallia, Guernsey, Hamilton, Harrison, Jefferson, Lorain, Madison, Medina, Meigs, Monroe, Morgan, Warren, Washington.**

Several specimens of this species were taken with prey, one a female with a male of *Perithemis tenera*, and the other a male feeding upon a crescent butterfly (*Phyciodes* sp.). Others were seen with the same prey, observations which confirm that reported for this species by Price (1958).

80 *Pantala flavescens* (Fabricius) 1798.—**Hamilton, Preble.**

81 *Pantala hymenea* (Say) 1839.—**Mahoning, Tuscarawas.**

83 *Tramea lacerata* Hagen 1861.—**Adams, Brown, Clark*, Columbiana, Gallia, Guernsey, Harrison, Jefferson, Lorain, Madison, Medina, Meigs, Miami, Monroe, Morgan, Muskingum, Stark, Summit, Warren.**

87 *Agrion maculatum* Beauvois 1805.—**Allen, Fayette†, Hardin, Harrison, Jefferson, Knox†, Madison, Meigs, Miami, Monroe, Morgan, Muskingum, Noble, Pike, Preble, Richland†, Sandusky, Shelby, Stark.**

88 *Hetaerina americana* (Fabricius) 1788.—**Allen, Butler, Gallia, Huron, Knox, Medina, Miami, Pike, Preble, Richland, Sandusky, Seneca.**

90 *Archilestes grandis* (Rambur) 1842.—**Cuyahoga** (E.S.M.).

This new record is a drastic extension of the range of this species. Previous collections had been made in the southwestern counties of Butler, Montgomery and Preble. The specimen from Cuyahoga County is a female that was collected by Eugene Morton at Rocky River. I made a pilgrimage to Oxford Butler County, to the area described by Williamson (1931) as the first Ohio locality reported for this species. Several specimens were taken there. The next day, September 3, this striking species was encountered again at Somerville, Butler County. This site, however, differed greatly from commonly reported habitats. Just across Seven Mile Creek from the village was a small (approximately 30 by 40 feet) muddy pond. It was situated at the base of a steep slope, had a gray clay bottom and was apparently fed by surface run-off. It was only some 100 feet from the creek. Considerable time was spent searching the creek bank and bottoms but to no avail. About the pond, however, large numbers were actively flying. They were very busily engaged in flying from perch to perch, coupling and copulating. None were seen to oviposit, however. These adults were rather easy to approach, so easy, that it was possible to photograph several despite lack of special equipment.

92a *Lestes disjunctus australis* Walker 1952. –**Coshocton†, Guernsey, Licking, Morrow, Muskingum†, Tuscarawas, Union†.**

Though Walker (1953) lists Ohio within the range of both subspecies, all specimens I have collected agree with his description of *L. d. australis*. The splitting of this species will require a reestablishment of the geographic and seasonal distributions. The seasonal distribution of this subspecies in Ohio has been given as April 20 (Kormondy, 1956) to June 6 (Price, 1958). The new records reported here range from May 6 to **August 12.**

97 *Lestes dryas* Kirby 1890.—**Licking.**

This single record also constitutes a change in seasonal distribution. Montgomery (1943) gives June 5 as the earliest date and Borror (1937) gives August 1 for the latest date [as *Lestes uncatus*]. Specimens were collected at Granville, Licking County on **May 13.**

95 *Lestes inequalis* Walsh 1862.—**Knox†, Vinton.**

96 *Lestes rectangularis* Say 1839.—**Allen†, Belmont, Columbiana, Crawford†, Darke, Guernsey, Hardin, Huron, Jackson†, Lorain, Madison, Mahoning, Medina, Miami, Pike, Preble†, Richland†, Summit, Union†, Wyandot.**

98 *Lestes unguiculatus* Hagen 1861.—**Crawford†, Marion†, Morrow†, Tuscarawas.**

99 *Lestes vigilax* Hagen 1862.—**Miami, Summit.**

100 *Argia apicalis* (Say) 1839.—**Allen, Carroll, Champaign, Clinton, Coshocton, Darke, Guernsey, Hancock, Harrison, Huron, Knox, Lawrence, Lorain, Madison, Medina, Meigs, Miami, Monroe, Morgan, Noble, Pickaway, Pike, Preble, Seneca, Union†, Wyandot.**

102 *Argia moesta* (Hagen) 1861.—**Allen, Guernsey, Harrison, Jefferson, Medina, Morrow, Sandusky, Seneca, Wood.**

At Fremont, Sandusky County, on August 26 many pairs of this species were seen ovipositing in the riffles of the Sandusky River. Such females showed great preference for plant material that was free floating and had been caught in the riffles. In several instances small, bobbing sticks were covered with enclasped pairs while large, solid pieces of wood were overlooked.

103 *Argia sedula* (Hagen) 1861.—**Darke†, Hardin, Harrison, Huron, Morrow, Muskingum.**

104 *Argia tibialis* (Rambur) 1842. **Allen, Fayette†, Guernsey, Hardin, Jefferson, Madison, Meigs, Morgan, Noble, Putnam, Shelby, Wood, Wyandot.**

146 *Argia translata* Hagen 1865.—**Harrison, Meigs.**

New State Record. The specimens (3 male and 1 female) collected in Harrison County were taken along the hard stoney shore of Piedmont Reservoir near the spillway. The single male from Meigs County was collected at Forked Run Lake. The seasonal distribution, based on these collections, is **June 30**; (Harrison County) to **July 9** (Meigs County).

105 *Argia violacea* (Hagen) 1861.—**Athens, Columbiana, Crawford, Gallia, Hancock, Hardin, Harrison, Hocking, Jackson, Jefferson, Lawrence, Lorain, Madison, Medina, Meigs, Monroe, Morgan, Muskingum, Pike, Preble†, Richland, Scioto, Seneca, Summit.**

106 *Amphiagrion saucium* (Burmeister) 1839. –**Ashtabula, Mahoning, Miami, Trumbull.**

108 *Nehalennia irene* (Hagen) 1861.—**Mahoning, Miami, Trumbull, Tuscarawas.**

109 *Chromagrion conditum* (Hagen) 1876.—**Madison, Mahoning.**

Borror (1937) gives the seasonal distribution of this species as May 20 to July 12. A single female collected at Big Darby Creek where it crosses the High Free Pike in Madison County extends its seasonal range to **May 5.**

110 *Enallagma antennatum* (Say) 1839. **Ashtabula, Belmont, Carroll, Champaign, Darke, Jefferson, Madison, Mahoning, Trumbull.**

111 *Enallagma aspersum* (Hagen) 1861. **Athens, Carroll, Gallia, Guernsey, Jackson, Jefferson, Knox†, Licking, Monroe, Muskingum, Stark, Summit, Tuscarawas, Vinton.**

The seasonal distribution of this species has been reported as May 7 (Borror, 1937) to August 2 (Price, 1958). This seasonal distribution is extended by collections at Lake Hope, Vinton County, on August 5 and at Porter, Gallia County, on **August 6.**

129 *Enallagma basidens* Calvert 1902. **Adams, Athens, Brown, Carroll, Champaign, Clark, Clinton, Crawford, Cuyahoga** (T.J.M.), **Darke, Franklin, Gallia, Guernsey, Hancock, Harrison, Huron, Licking, Logan, Lorain, Meigs, Miami, Monroe, Morgan, Morrow, Muskingum, Pickaway, Pike, Preble, Scioto, Union, Warren.**

This species was first reported in Ohio by Borror (1938) with records from Clermont and Montgomery Counties. Since that time Montgomery (1943) and Price (1950, 1958) have added records from six northwestern counties. These records little reflect the distribution of this relatively new addition to the Ohio fauna, for it is now apparently widespread throughout the state. In fact, at some habitats it was the most common damselfly. As it further extends its range it may again illustrate the success of invading organisms.

113 *Enallagma carunculatum* Morse 1895. **Carroll, Columbiana, Medina, Miami.**

114 *Enallagma civile* (Hagen) 1861. **Adams, Athens, Brown, Carroll, Champaign, Clinton, Columbiana, Crawford, Gallia, Guernsey, Hancock, Hardin, Harrison, Highland, Hocking,**

Huron, Jefferson, Lawrence, Lorain, Madison†, Mahoning, Marion, Medina, Miami, Morgan, Morrow, Muskingum, Pickaway, Pike, Preble, Scioto†, Shelby, Union†, Vinton, Warren, Wyandot.

115 *Enallagma divagans* Selys 1876.—**Ashtabula, Trumbull.**

118 *Enallagma exsulans* (Hagen) 1861.—**Allen, Champaign, Crawford†, Gallia, Guernsey, Huron, Jefferson, Medina, Meigs, Monroe, Pike, Putnam, Scioto, Seneca, Wyandot.**

119 *Enallagma geminatum* Kellicott 1895.—**Allen†, Clark, Columbiana, Crawford, Greene, Jefferson, Mahoning, Medina, Morrow, Muskingum, Preble, Union, Warren.**

121 *Enallagma signatum* (Hagen) 1861.—**Belmont, Brown, Carroll, Clark, Columbiana, Crawford, Hamilton, Harrison, Hocking†, Jackson, Miami, Morrow, Muskingum, Pike, Preble, Union†, Warren.**

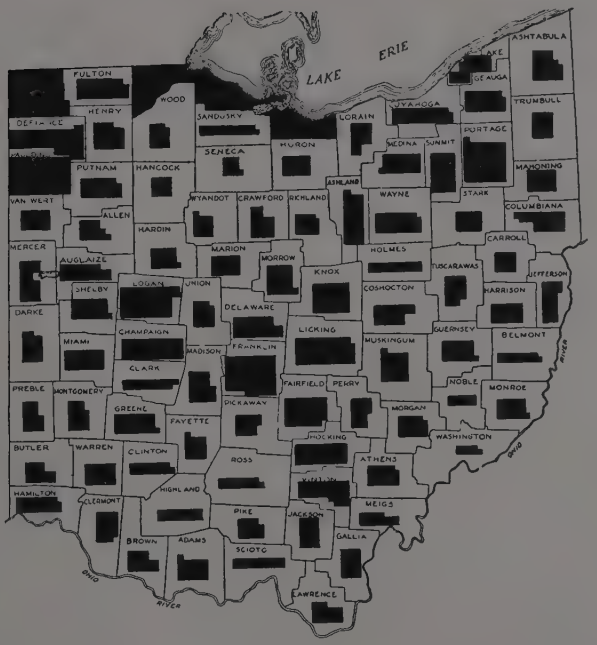

FIGURE 2. Distribution of county records for Odonata reported from Ohio. The total number of records reported for each county are indicated proportionately. Those counties totally blackened may have more records than the available area permits indicating.

This species is mentioned by Howe (1917) as being semicrepuscular. Field observations concur in this for it is rarely active before late afternoon. It is the latest flier of the damselflies, often flying when the light is so weak they can hardly be seen. During mid-day it is found only in heavily shaded situations. Apparently, this is a heliophobic species rather than heliophilic as are most Odonata. Adults when flying skim just above the surface of the water, and when at rest choose floating materials. They are uncommon along the shore.

123 *Enallagma vesperum* Calvert 1919.—**Lawrence.**

124 *Ischnura posita* (Hagen) 1861.—**Adams, Auglaize, Brown, Clark, Darke, Hancock, Hardin, Hocking, Lorain, Medina, Meigs, Miami, Monroe, Morgan, Pike, Sandusky, Scioto, Trumbull, Warren.**

126 *Ischnura verticalis* (Say) 1839.—**Adams, Allen, Athens, Carroll, Crawford, Guernsey, Hamilton, Hardin, Harrison, Highland, Huron, Jefferson, Lawrence, Lorain, Medina, Meigs, Monroe, Morgan, Noble, Preble, Richland, Scioto, Seneca, Wyandot.**

The above records bring the total to 88 counties, the first species to have been reported from every county in the state. This of course is no surprise and only reflects the fact that all the counties have now been investigated by a collector of Odonata. This species is truly ubiquitous. Rarely is it absent where any aquatic insect life can exist. A female of this species was taken with prey that appeared to be a teneral damselfly.

127 *Anomalagrion hastatum* (Say) 1839.—**Athens†, Clermont, Hardin, Licking, Lorain, Morrow.**

TABLE 3

Number of species reported for Ohio counties

	Anisoptera	Zygoptera	Total		Anisoptera	Zygoptera	Total
Adams	14	11	25	Licking	30	29	59
Allen	10	9	19	Logan	32	31	63
Ashland	23	18	41	Lorain	11	9	20
Ashtabula	16	14	30	Lucas	26	22	48
Athens	13	10	23	Madison	13	14	27
Auglaize	14	14	28	Mahoning	9	17	26
Belmont	9	8	17	Marion	12	10	22
Brown	10	10	20	Medina	16	13	29
Butler	9	11	20	Meigs	12	9	21
Carroll	8	8	16	Mercer	14	15	29
Champaign	24	24	48	Miami	14	16	30
Clark	9	12	21	Monroe	12	9	21
Clermont	11	12	23	Montgomery	5	17	22
Clinton	4	11	15	Morgan	15	8	23
Columbiana	18	13	31	Morrow	13	19	32
Coshocton	19	10	29	Muskingum	16	15	31
Crawford	11	9	20	Noble	7	4	11
Cuyahoga	17	18	35	Ottawa	30	18	48
Darke	6	16	22	Paulding	52	30	82
Defiance	42	27	69	Perry	14	7	21
Delaware	21	15	36	Pickaway	9	9	18
Erie	38	30	68	Pike	9	11	20
Fairfield	22	22	44	Portage	37	29	66
Fayette	6	11	17	Preble	10	11	21
Franklin	48	30	78	Putnam	18	13	31
Fulton	18	21	39	Richland	13	6	19
Gallia	12	10	22	Ross	8	9	17
Geauga	19	13	32	Sandusky	10	13	23
Greene	16	17	33	Scioto	12	8	20
Guernsey	14	11	25	Seneca	8	6	14
Hamilton	20	6	26	Shelby	14	15	29
Hancock	8	8	16	Stark	8	12	20
Hardin	12	9	21	Summit	23	16	39
Harrison	15	10	25	Trumbull	7	12	19
Henry	15	13	28	Tuscarawas	12	11	23
Highland	10	8	18	Union	7	12	19
Hocking	25	14	39	Van Wert	13	9	22
Holmes	12	10	22	Vinton	22	15	37
Huron	12	10	22	Warren	13	12	25
Jackson	14	10	24	Washington	5	4	9
Jefferson	16	10	26	Wayne	21	15	36
Knox	24	18	42	Williams	62	39	101
Lake	12	13	25	Wood	8	11	19
Lawrence	11	10	21	Wyandot	10	7	17

TABLE 4

Species of Odonata reported from Ohio

Anisoptera				Zygoptera	
1	*Tachopteryx thoreyi*	128	*Macromia pacifica*	85	*Agrion aequabile*
2	*Progomphus obscurus*	45	*Macromia taeniolata*	86	*Agrion angustipenne*
3	*Hagenius brevistylus*	135	*Macromia wabashensis*	87	*Agrion maculatum*
4	*Ophiogomphus rupinsulensis*	46	*Didymops transversa*	88	*Hetaerina americana*
5	*Erpetogomphus designatus*	47	*Neurocordulia obsoleta*	89	*Hetaerina titia*
6	*Gomphus abbreviatus*	48	*Neurocordulia yamaskanensis*	90	*Archilestes grandis*
7	*Gomphus amnicola*	49	*Epicordulia princeps*	91	*Lestes congener*
8	*Gomphus crassus*	50	*Tetragoneuria cynosura*	92	*Lestes disjunctus* [*s.l.*]
9	*Gomphus exilis*	145	*Helocordulia uhleri*	92a	*Lestes d. australis*
138	*Gomphus externus*	134	*Somatochlora ensigera*	92b	*Lestes d. disjunctus*
10	*Gomphus fraternus*	51	*Somatochlora hineana*	97	*Lestes dryas*
11	*Gomphus furcifer*	133	*Somatochlora linearis*	93	*Lestes eurinus*
12	*Gomphus graslinellus*	52	*Somatochlora tenebrosa*	94	*Lestes forcipatus*
136	*Gomphus laurae*	132	*Dorocordulia libera*	95	*Lestes inequalis*
13	*Gomphus lineatifrons*	53	*Nannothemis bella*	96	*Lestes rectangularis*
14	*Gomphus lividus*	54	*Perithemis tenera*	98	*Lestes unguiculatus*
15	*Gomphus notatus*	55	*Celithemis elisa*	99	*Lestes vigilax*
16	*Gomphus plagiatus*	56	*Celithemis eponina*	100	*Argia apicalis*
17	*Gomphus quadricolor*	57	*Celithemis monomelaena*	101	*Argia bipunctulata*
18	*Gomphus spicatus*	58	*Erythrodiplax minuscula*	130	*Argia fumipennis*
19	*Gomphus spiniceps*	59	*Erythrodiplax umbrata*	102	*Argia moesta*
20	*Gomphus vastus*	60	*Ladona julia*	103	*Argia sedula*
21	*Gomphus ventricosus*	61	*Libellula auripennis*	104	*Argia tibialis*
22	*Gomphus villosipes*	62	*Libellula cyanea*	146	*Argia translata*
23	*Gomphus viridifrons*	63	*Libellula incesta*	105	*Argia violacea*
24	*Dromogomphus spinosus*	64	*Libellula luctuosa*	106	*Amphiagrion saucium*
25	*Dromogomphus spoliatus*	66	*Libellula pulchella*	107	*Nehalennia gracilis*
26	*Lanthus albistylus*	67	*Libellula quadrimaculata*	108	*Nehalennia irene*
27	*Gomphaeschna antilope*	68	*Libellula semifasciata*	109	*Chromagrion conditum*
28	*Basiaeschna janata*	69	*Libellula vibrans*	137	*Coenagrion resolutum*
29	*Boyeria grafiana*	(65)	*Plathemis lydia*	110	*Enallagma antennatum*
30	*Boyeria vinosa*	70	*Sympetrum ambiguum*	111	*Enallagma aspersum*
31	*Anax junius*	144	*Sympetrum costiferum*	129	*Enallagma basidens*
32	*Anax longipes*	143	*Sympetrum internum*	112	*Enallagma boreale*
131	*Coryphaeschna* (*ingens?*)	72	*Sympetrum obtrusum*	113	*Enallagma carunculatum*
33	*Nasiaeschna pentacantha*	73	*Sympetrum rubicundulum*	114	*Enallagma civile*
34	*Epiaeschna heros*	74	*Sympetrum semicinctum*	140	*Enallagma cyathigerum*
141	*Aeshna canadensis*	75	*Sympetrum verum*	115	*Enallagma divagans*
35	*Aeshna clepsydra*	76	*Sympetrum vicinum*	116	*Enallagma doubledayi*
36	*Aeshna constricta*	(71)	*Tarnetrum corruptum*	117	*Enallagma ebrium*
142	*Aeshna interrupta*	77	*Leucorrhinia intacta*	118	*Enallagma exsulans*
37	*Aeshna mutata*	78	*Pachydiplax longipennis*	119	*Enallagma geminatum*
38	*Aeshna umbrosa*	79	*Erythemis simplicicollis*	120	*Enallagma hageni*
39	*Aeshna verticalis*	80	*Pantala flavescens*	121	*Enallagma signatum*
40	*Cordulegaster diastatops*	81	*Pantala hymenea*	122	*Enallagma traviatum*
41	*Cordulegaster erroneus*	82	*Tramea carolina*	123	*Enallagma vesperum*
42	*Cordulegaster maculatus*	83	*Tramea lacerata*	124	*Ischnura posita*
43	*Cordulegaster obliquus*	84	*Tramea onusta*	125	*Ischnura prognatha*
139	*Macromia alleghaniensis*			126	*Ischnura verticalis*
44	*Macromia illinoiensis*			127	*Anomalagrion hastatum*

SUMMATION OF ODONATA REPORTED FOR OHIO

In order that the Ohio list of Odonata may once again be brought together in one place, and in an attempt to encourage the publication of data significant in completing the knowledge of the Ohio fauna, the following materials have been prepared.

Space limitations prohibit the publication of a complete total list of county

records. Therefore, such records are indicated in two forms. Figure 2 attempts to illustrate graphically the total records for each county listed in table 3. The block areas are proportional; hence, one can quickly see the many extensive areas of the state needing further investigation.

Table 4 is not intended to be a checklist. Instead it is merely a summation of those species known to have been reported from the state. Though space does not permit indication of the author responsible for each record, all such references are included within the paper.

SUMMARY

Field investigations in 68 of the counties of Ohio have resulted in 597 new county records involving 66 species and the addition of *Argia translata* Hagen to the Odonta known to occur in Ohio. A review of the species reported for Ohio is given relative to the assignment of numbers for the state list. Data pertinent to the new records, including field observations of ecology and behavior, are given for 29 of the species. Tables and maps are included to illustrate the distribution of sites visited, frequency of reported records per county, and a list of the species reported for Ohio.

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SOILS OF THE HIGH TERRACE REMNANTS IN THE UPPER OHIO VALLEY

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INTRODUCTION

Soils on the high terrace remnants along the upper reaches of the Ohio River are similar to the dominant ones of the nearby uplands in some instances, but not in others. Major soils of the bordering uplands are members of the Gray-Brown Podsolic and associated groups (U. S. Dept. of Agriculture, 1938, pp. 1043–1044), which also include some of the soils on the high terraces. Certain soils on the terraces, however, have many characteristics of the Red-Yellow Podsolic group. Reasons for this are not readily apparent, though there seem to be several possible explanations. In an effort to gain further insight into their nature and origin, four profiles representative of major soils of the high terraces were examined carefully and described in detail. Two profiles were sampled by horizons for laboratory analysis. The lithology of the sediments in the terrace remnants was also studied to get some measure of its bearing on present soil character. These sediments, as they exist today, are in fact largely also soils and the nature of the highest level of glacial outwash is best described by description of its soil morphologies. Results of the study are reported in this paper.

DISTRIBUTION, TOPOGRAPHY, AND EXTENT OF THE TERRACES

Remnants of a high glacial outwash terrace, preserved mainly in former stream meanders, are scattered along the upper Ohio Valley (Leverett, 1902, pp. 84–94, 121–125, 1929, p. 229, 1934, pp. 101–102; Ireland, 1940, 1943; Hubbard, 1954). These lie mainly along the valley walls south of the glacial boundary (White, 1951), which is about 8 miles north of the study area.

These terrace remnants, lying at elevations of 960 to 1020 ft are the highest of four glacial outwash terrace levels along the Ohio River. Lower terraces occur at general elevations of 720, 760, and 850 ft. In the study area, the present channel of the Ohio River is at an elevation of approximately 650 ft. Uplands bordering the river valley consist of the knobs and ridges of the unglaciated but dissected Allegheny Plateau, largely between elevations of 1160 and 1260 ft. The general region is thus dominantly hilly.

The terrace remnants have been partly dissected but are gently sloping for the most part. The valley edges are marked by escarpments, though outcrops of bedrock form hills between a terrace remnant and the river channel in places.

The total area of the terrace remnants is not large, even though they are scattered along a considerable stretch of the river. Individual bodies are small, commonly ranging from one-half to a mile in width.

They are found at the Riverview Greenhouse, Chester (Leverett, 1934, pp. 101–102), the low level reservoir in East Liverpool (Leverett, 1902, p. 252), Spring Grove (fig. 1), Vulcan, Tomilson Run and Toronto (Leverett, 1902, p. 250), Globe Hill (Lessig, 1959a), south of New Cumberland (fig. 3) and between Salt Run and Rush Run (fig. 3).

SOIL PROFILE STUDY METHODS

Soil profiles were studied on two terrace remnants, one near East Liverpool and the other just west of Vulcan and Wellsville, Ohio (Hubbard, 1954, p. 368). The remnant near East Liverpool (fig. 1) will be called the Riverview Greenhouse Terrace in this paper, the name of a greenhouse on the terrace itself. The remnant

west of Vulcan and Wellsville will be called the Vulcan Terrace. Specific locations of these profiles are given with the data on their morphology.

Profile descriptions follow the conventions and terminology outlined in the Soil Survey Manual (Soil Survey Staff, 1951), except as noted subsequently. Conventions for characterizing quantities of pebbles and the coats and stains of various kinds on ped faces are not provided in the Soil Survey Manual. Consequently, the quantities of pebbles are indicated as estimated percentages by volume and they were identified visually, by means of a hand lens, where such identification is noted. Coatings and stains on ped faces are described in terms of color according to Munsell notations, and in terms of estimated thickness and texture. Soil horizon colors are given for moist conditions and include Munsell notations. Determinations of pH, made colorimetrically in the field, are given in the profile descriptions but those reported in tables 1 and 2, together with data

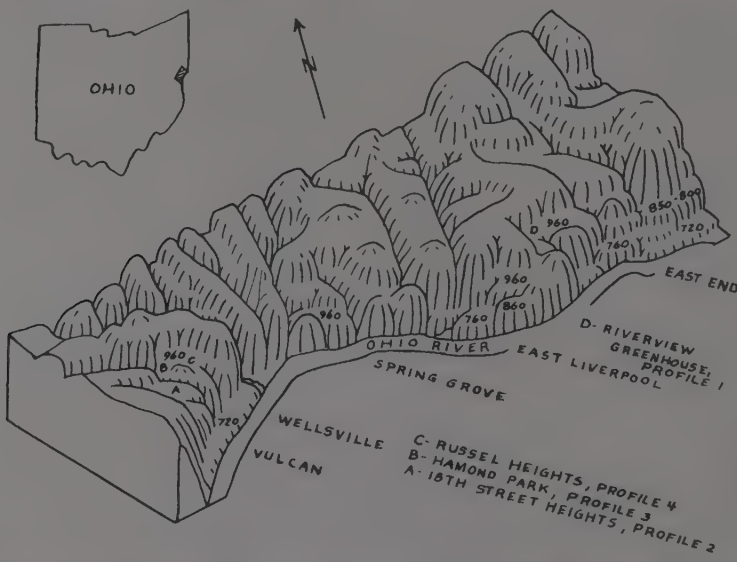

FIGURE 1. Block diagram of region around the Riverview Greenhouse and Vulcan Terraces.

on particle size distribution are laboratory determinations. Mechanical analyses were made in the laboratories of the Ohio Agricultural Experiment Station, according to the procedure described by Kilmer and Alexander (1949).

SOIL PROFILE ON THE RIVERVIEW GREENHOUSE TERRACE

This terrace remnant has a total area of about 300 acres and lies little more than one-half a mile north of the Ohio River near East Liverpool. The terrace forms parts of Secs. 12, 18 and 35 Liverpool Township, Columbiana County, Ohio (Wellsville, Ohio, W. Va-Pa. quadrangle map of the U. S. Geological Survey).

The profile was described and sampled at a point 900 ft southeast of the Riverview Greenhouse, which is at the corner of Anderson Boulevard and Thompson Park Road in East Liverpool. Approximately 1500 ft from the terrace escarpment, the site is in the north-central part of Sec. 18 and has a convex slope of 3 percent. Elevation is 1005 ft above sea level.

The glacial outwash in the terrace remnant ranges in thickness from 1 to 40 ft, with thick deposits occuring up to 1020 ft. In places near the valley wall, the outwash is covered by deeply weathered colluvium. Underlying bedrock has been observed at elevations of 960 ft or slightly less, though there are two hills of bedrock between the terrace remnant and the Ohio River.

Profile 1.—Description of well-drained profile from silty alluvium over glacial outwash. (Described and sampled by W. H. Hale and H. D. Lessig)

Depth and Horizon	*Profile Description*
0–2 in. A_1	Very dark grayish brown (10YR 3/2) silt loam; weak very fine crumb structure; friable; pebbles 3%; neutral (field limed); boundary abrupt smooth.
2–10 in. A_2	Dark brown (10YR 4/3) silt loam with few coarse faint very dark gray (10YR 3/1) stains; weak fine crumb structure; friable; rotted pebbles 3%; neutral; boundary abrupt smooth.
10–16 in. B_1	Dark brown (9YR 4/4) silt loam; moderate medium subangular blocky structure; dark grayish brown (10YR 4/2) 2 mm thick silty coats on ped faces; friable; rotted pebbles 1%; strongly acid; boundary clear smooth.
16–23 in. B_{21}	Dark brown (7.5YR 4/4) fine silt loam with common fine black Mn stains; moderate medium subangular blocky structure; very thin reddish brown (5YR 4/4) clay coats on ped faces; friable; rotted pebbles 3%; strongly acid; boundary clear smooth.
23–44 in. B_{22}	Strong brown (7.5YR 4/6) and yellowish red (5YR 4/5) sandy clay loam; strong medium angular blocky grading to strong coarse angular blocky structure; very thin reddish brown (5YR 4/4) and black Mn stained clay coats on ped faces; firm; rotted pebbles 10%; strongly acid; boundary gradual.
44–92 in. B_{23}	Yellowish red (5YR 4/6) gravelly sandy clay loam to sandy loam with common medium black Mn stains; moderate very coarse subangular blocky structure breaking to thick platy peds; 1 mm thick yellowish red (5YR 4/8) clay coats on horizontal ped faces, very thin strong brown (7.5YR 4/6) clay coats on vertical ped faces; firm; rotted pebbles 30%; strongly acid; boundary gradual.
92–108 in. B_3	Strong brown (7.5YR 4/6) gravelly loamy sand with many coarse faint dark yellowish brown (10YR 4/4) mottles; very weak coarse subangular blocky structure; black Mn stains on ped faces; firm in place, friable when disturbed; clay coated rotted pebbles 50%; strongly acid; boundary gradual.
108–120 in. C_{11}	Dark brown (10YR 4/3) gravelly loamy sand with many coarse black Mn stains; single grain structure; firm in place, very friable when disturbed; rotted pebbles 70% which crush in the fingers when rubbed; strongly acid; boundary gradual.
120–204 in. C_{12}	Dark reddish brown (5YR 4/4) gravelly sandy loam; single grain structure; very friable to non-coherent at 204-in. depth; pebbles 70% becoming harder at 204 in., pebble count of 950 pieces:—oxidized sandstone and siltstone which break in the fingers 69%, chert ghosts 6%, strongly altered quartzites 12%, ghosts of granite and other crystalline rocks 9%, concretions 4%; strongly acid. Note:—Gravel extends to 40-ft depth according to landowner and observation on nearby terrace escarpment, large crystalline cobbles are found in nearby excavations.

Major morphological features are: lack of well-defined fragipan, a well-drained profile, clay formed to 92 in. and clay coating on pebbles to 108 in., reddish hue

TABLE 1

Partical size distribution (in mm) (percent) of soil at Profile 1

Depth in inches	Horizon	Very coarse sand 2–1	Coarse sand 1–0.5	Medium sand 0.5–0.25	Fine sand 0.25–0.1	Very fine sand 0.1–0.05	Total sand	Silt 0.05–0.002	Clay <0.002	Fine clay <0.0002	pH
0–2	A_1	1.1	3.1	4.2	4.6	4.4	17.4	66.3	16.3	4.8	6.6
2–10	A_2	0.9	2.7	4.1	4.8	4.0	16.5	66.8	16.7	4.1	4.8
10–16	B_1	0.4	2.3	3.9	4.3	3.3	14.2	64.9	20.9	6.3	4.8
16–23	B_{21}	0.5	3.3	6.2	7.3	5.1	22.4	55.1	22.5	9.4	4.8
23–28	B_{22}	0.9	7.7	16.7	20.1	8.3	53.7	23.5	22.8	10.1	4.7
28–34	B_{23}	1.0	7.4	17.1	20.7	8.4	54.6	23.5	21.9	9.6	4.7
34–44	B_{22}	1.1	8.9	18.6	21.4	7.9	57.9	21.1	21.0	10.2	4.7
44–64	B_{23}	1.3	10.5	20.1	22.9	8.0	62.8	18.7	18.5	7.9	4.8
64–82	B_{23}	2.2	12.7	22.3	24.5	8.5	70.2	15.8	14.0	6.2	4.8
82–92	B_{23}	3.6	20.4	22.6	20.0	7.9	74.5	11.7	13.8	5.2	4.7
92–108	B_{31}	8.8	23.0	20.3	18.2	9.3	79.6	12.7	7.7	2.4	5.1
108–120	C_1	9.7	31.4	14.4	14.3	10.9	80.7	12.4	6.9	2.9	4.9
120–144	C_1	6.3	24.6	12.8	17.6	14.7	76.0	18.0	6.0	1.1	5.0
144–168	C_1	5.1	12.8	18.9	21.7	13.9	72.4	19.5	8.1	2.0	5.1
168–204	C_1	8.5	27.9	15.8	14.2	10.6	77.0	15.5	7.5	1.0	5.0

TABLE 2

Partical size distribution (in mm) (percent) of soil at Profile 3

Depth in inches	Horizon	Very coarse sand 2–1	Coarse sand 1–0.5	Medium sand 0.5–0.25	Fine sand 0.25–0.1	Very fine sand 0.1–0.05	Total sand	Silt 0.05–0.002	Clay <0.002	Fine clay <0.0002	pH
0–1	A_1	3.5	3.2	1.5	2.4	2.7	13.3	74.6	12.1	2.8	3.7
1–6	A_2	1.7	1.9	0.5	0.5	1.0	5.6	74.9	19.5	4.8	4.0
6–9	A_3	1.3	1.9	0.7	0.7	1.1	5.7	76.9	17.4	3.5	4.4
9–14	B_1	0.8	1.2	0.4	0.4	1.3	4.1	68.2	27.7	10.5	4.7
14–22	B_{21g}	0.5	1.0	0.5	0.8	1.8	4.6	54.1	41.3	24.2	4.7
22–32	B_{22}	1.5	1.9	1.0	1.6	3.1	9.1	59.3	31.6	10.5	4.8
32–42	B_{23}	2.2	3.3	1.6	2.4	3.9	13.4	55.0	31.6	9.7	5.1
42–48	B_{31}	0.7	1.1	0.7	1.1	2.4	6.0	64.4	29.6	8.4	5.5
48–55	B_{22}	0.7	1.3	0.8	1.2	1.8	5.8	50.1	44.1	14.0	6.0
55–60	B_{22}	1.5	2.3	1.7	2.4	2.6	10.5	45.2	44.3	14.9	5.8
60–80	B_{23}	0.5	1.6	1.0	1.4	1.6	6.1	43.7	50.2	16.9	6.5
80–110	B_{22}	0.1	0.1	0.2	0.3	0.2	0.9	44.0	55.1	12.3	7.0
110–135	C	0.1	0.1	0.5	1.1	0.6	2.4	37.0	60.6	15.3	7.4
135–153	$D_1(A_b)$	0.1	3.6	36.9	39.3	4.8	84.7	7.6	7.7	2.3	7.4
153–160	$D_2(B_{1b})$	0.1	3.0	17.5	33.2	14.0	67.8	17.4	14.8	6.3	7.4
160–190	$D_3(B_{2b})$	0.1	0.3	3.5	29.4	21.7	55.0	27.8	17.2	6.9	6.4
190–240	$D_4(C_b)$	0.1	0.2	5.7	45.1	20.1	71.2	17.1	11.7	4.6	6.3

with a strong chroma in the soil horizons between 23 to 92 in. These are properties of Red-Yellow Podsolic Soils (Simonson, 1950).

The upper part of the solum, with a slightly different morphology, is formed in silty material (table 1) which is common to these high terrace remnants on the Ohio side of the river. It contains a few cobbles and pebbles, does not extend as a silty mantle to nearby higher surfaces and contains about 4 percent of coarse and very coarse sand. It is interpreted by the author to be of alluvial origin

rather than wind deposited. Its color and structure tend to grade to the color and structure of the underlying gravelly horizon. A soil developed in wind deposited material at Globe Hill on the West Virginia side (Lessig, 1959a) has only 0.7 percent of coarse and very coarse sand. However, without more conclusive evidence, contamination by loess cannot be precluded from the silty layer on the Riverview Greenhouse Terrace.

SOIL PROFILES ON THE VULCAN TERRACE

This terrace remnant occupies an area of about 450 acres a half mile northwest of the Ohio River near Vulcan and Wellsville, in parts of Secs. 10, 15 and 16, Yellow Creek Township. It is occupied by the suburbs of Russel Heights, 18th Street Heights and Hamond Park.

The bedrock surface beneath the Vulcan Terrace is irregular, ranging from 1010 to below 940 ft. The material covering the bedrock belongs to several geological events. Sandy and gravelly glacial outwash covers the bedrock at most places where it was observed, but in some positions near the valley wall the outwash is covered by 2 to 11 ft of lacustrine material. This is calcareous at a 9-ft depth (Profile 3). At the valley wall, the lacustrine material is underlain

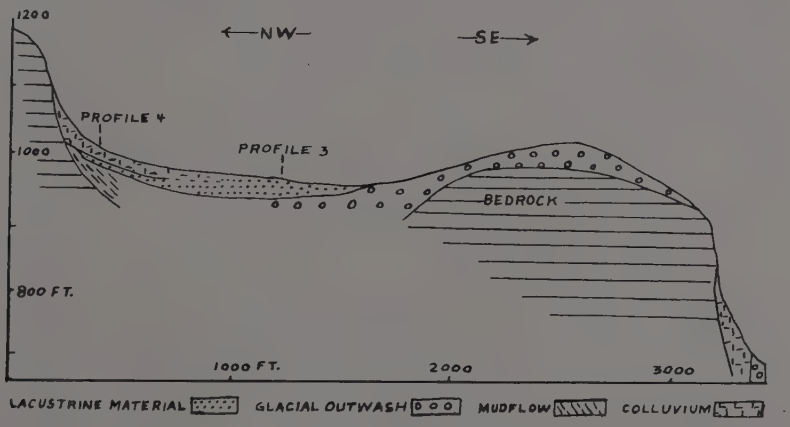

FIGURE 2. Section through Vulcan Terrace at Hamond Park.

by a thick mudflow from local higher rock layers and overlain by colluvium which is poorly sorted as though deposited in shallow water near a shore (Profile 4). Upslope the colluvium is much thicker and is not sorted.

The glacial outwash varies within short distances from silty and sandy alluvium, containing a few pebbles, to gravelly outwash. At 18th Street Heights large cobbles of crystalline rocks are frequent while only a few are found at Russel Heights. The soil developed in the gravelly outwash is similar to that at the Riverview Greenhouse and comments with regard to morphological data on the profile on the Riverview Greenhouse Terrace largely apply to the gravelly soils of the Vulcan Terrace.

The morphology of a soil developed from silty and sandy outwash at 18th Street Heights is described at a point 150 ft west of the terrace escarpment between two houses at the south end of West Street. It is on a three percent slope in the southwest corner of Sec. 10, Yellow Creek Township. Elevation is 980 ft above sea level.

Profile 2.—Description of a moderately well drained intergrading to a well-drained profile from silty glacial outwash over sandy glacial outwash. (Described and sampled by W. H. Hale and H. D. Lessig)

Depth and Horizon	*Profile Description*
0–1 in. A_1	Black (N 2/0) silt loam; moderate very fine crumb structure; friable; no pebbles in sample, large cobbles of sandstone and quartzite in area of sample pit; extremely acid; boundary abrupt wavy.
1–8 in. A_2	Very dark grayish brown (10YR 3/2) silt loam with coarse irregular zones of A_1 tonguing into A_2; moderate medium platy structure breaking into weak fine granular peds; friable; no pebbles; extremely acid; boundary abrupt smooth.
8–11 in. A_3	Dark brown (7.5YR 3/4) silt loam with dark gray (10YR 4/1) in vertical cracks, crushed color dark brown (10YR 4/3); moderate fine granular structure; friable; no pebbles; extremely acid; boundary abrupt smooth.
11–18 in. B_1	Dark brown (10YR 4/3) fine silt loam with dark brown (7.5YR 3/2) in vertical cracks; weak medium subangular blocky structure; friable; no pebbles; very strongly acid; boundary abrupt smooth.
18–24 in. B_{21}	Yellowish brown (10YR 5/4) silt loam; moderate medium subangular blocky structure; friable; strongly weathered pebbles 3%; strongly acid; boundary abrupt smooth.
24–29 in. B_{22}	Yellowish brown (10YR 5/4) coarse silty clay loam with common medium distinct strong brown (7.5YR 4/6) mottles; moderate medium subangular blocky structure; very thin brown (10YR 5/3) coats and coarse black Mn stains on ped faces; slightly firm; pebbles 5%; strongly acid; boundary abrupt smooth. Note: gravelly zone 10 ft horizontally away, imbedded in the silty alluvium, is mottled, has strong angular blocky structure, is extremely firm and contains 75% pebbles of local rocks and 25% of quartzite and chert, all strongly weathered.
29–39 in. B_{23m}	Brown (9YR 4/4) clay loam with common medium prominent yellowish red (4YR 4/6) mottles; fragipan breaking to strong medium angular blocky peds; 5 mm thick dark grayish brown (10YR 4/2) clay coats on vertical ped faces, thin yellowish brown (10YR 5/4) coats on horizontal ped faces; extremely firm; strongly weathered pebbles 5%, a few cobbles; strongly acid; boundary abrupt smooth.
39–48 in. B_{24m}	Strong brown (7.5YR 4/6) loam to sandy clay loam with few black Mn stains; fragipan with strong coarse angular blocky structure breaking to moderate very thick platy peds; 8 mm thick dark grayish brown (10YR 4/2) clay coats on vertical ped faces, very thin dark brown (7.5YR 4/4) clay coats on horizontal ped faces; very firm; a few cobbles; strongly acid; boundary clear smooth.
48–66 in. B_{31}	Strong brown (7.5YR 5/6) sandy loam; weak very coarse prismatic structure; very thin dark grayish brown (9YR 4/2) clay coats on prism faces; firm in place, friable when disturbed; pebbles 1%, a few cobbles; strongly acid; boundary gradual.
66–76 in. B_{32}	Yellowish brown (10YR 5/4) sandy loam with yellowish red (5YR 5/8) sandy horizontal zones; weak very coarse prismatic structure; very thin dark brown (7.5YR 3/4) clay coats on prism faces; firm in place, friable when disturbed; pebbles 10%; strongly acid; boundary gradual.
76–102 in. C_1	One inch thick layers of brown (10YR 5/3) silt and strong brown (7.5YR 4/6) sand with zones of fine black Mn stains; massive

breaking to platy fragments along bedding planes; friable; pebbles 5% occuring in thin layers of fine gravel; strongly acid; boundary gradual. Note: site 50 ft to the south is gravelly at this depth, alluvium is 20 ft thick.

The morphology of this soil differs from that described in Profile 1 in that it has a higher clay content throughout, a thinner zone of clay accumulation, more cobbles on the surface and throughout the profile, a finer textured parent material, a strong fragipan and a more yellowish hue. The profile is like that of the Gray-Brown Podsolic Soils of uplands of the region. However it was noted during field study that the color and structure vary in this profile whenever the lithology becomes more sandy and gravelly. It is also noted that the horizontal ped faces have more reddish coats than the vertical faces.

The silty material at 0 to 29 in. is like that material at 0 to 23 in. in Profile 1. Here on the Vulcan Terrace some of it is buried beneath the gravelly zone described under the B_{22} horizon, at 24 to 29 in., and large cobbles are found on it and in it.

Areas of imperfectly drained soil are also found on these terraces. Its morphology and origin was studied at Hamond Park (fig. 1). Here at Profile 3 the imperfectly drained soil is formed in lacustrine material which is underlain by a buried paleosol formed in sandy outwash.

The profile was sampled and described at a point 100 ft north of the road around Hamond Park, located in the SE¼ NE¼ Sec. 10, Yellow Creek Township. The site has a one percent even slope. It is at 960 ft above sea level.

Profile 3.—Description of imperfectly drained soil profile from lacustrine material over sandy outwash. (Described and sampled by W. H. Hale and H. D. Lessig)

Depth and Horizon	*Profile Description*
½–0 in. A_0	Black mull grading to mor, fibrous mat of roots, decomposition seems to be retarded; boundary abrupt smooth.
0–1 in. A_1	Black (N 2/0) coarse silt loam; weak very fine granular structure; friable; no pebbles; extremely acid; boundary abrupt wavy.
1–6 in. A_2	Brown (10YR 5/3) silt loam with few medium faint dark yellowish brown (10YR 4/4) mottles and gray (10YR 5/1) vertical stains, crushed color light brownish gray (10YR 6/2); weak fine granular structure; friable; no pebbles; very strongly acid; boundary abrupt wavy.
6–9 in. A_3	Grayish brown (10YR 5/2) silt loam with many medium distinct yellowish brown (10YR 5/6) mottles; weak medium granular to weak very fine subangular blocky structure; dark gray (10YR 4/1) stains on ped faces; friable; no pebbles; very strongly acid; boundary abrupt smooth.
9–14 in. B_1	Faintly mottled brown (10YR 5/3) and dark brown (7.5YR 4/4) silt loam; moderate medium subangular blocky structure; 2 mm thick brown (10YR 5/3) degraded clay coats on ped faces; friable; no pebbles; very strongly acid; boundary clear smooth.
14–22 in. B_{21g}	Strong brown (7.5YR 5/6) silty clay loam to silty clay with many medium prominent gray (10YR 5/1) and reddish brown (5YR 4/4) mottles; moderate coarse angular blocky structure breaking to strong fine angular blocky peds; 2 mm thick light brownish gray (10YR 6/2) silty clay coats on ped faces; less friable than B_1 but not firm; no pebbles; very strongly acid; boundary abrupt wavy.
22–32 in. B_{22m}	Strong brown (7.5YR 5/6) silty clay loam; weak fragipan with very weak coarse prismatic structure breaking to strong coarse angular

	blocky peds; 2 to 10 mm thick grayish brown (10YR 5/2) and gray (N 6/0) clay coats on ped faces and many black Mn stains on blocky peds; firm; small pebbles, concretions and channers 5%; material is laminated; very strongly acid; boundary gradual.
32–42 in. B_{23m}	Dark yellowish brown (10YR 4/4) fine silty clay loam with common medium faint grayish brown (2.5Y 5/2) mottles and coarse black Mn stains; weak fragipan with strong fine angular blocky structure; 2 mm thick grayish brown (2.5Y 5/2) clay coats on ped faces; firm; small pebbles and channers 5%; material is laminated with clay flows on laminae; strongly acid; boundary gradual.
42–48 in. B_{31m}	Dark yellowish brown (10YR 4/6) silty clay loam with common coarse distinct light brownish gray (2.5Y 6/2) mottles and black Mn stains; weak fragipan with weak coarse angular blocky structure; firm; no pebbles; material is laminated with light brownish gray (10YR 6/2) clay flows on laminae; strongly acid ranging to slightly acid in lower part; boundary gradual.
48–60 in. B_{32m}	Yellowish brown (10YR 5/6) silty clay loam with few black Mn stains; weak fragipan; 3 mm thick vertical gray (10YR 5/1) clay seams; firm; few pebbles; slightly acid; boundary and structure not determined, sampled with bucket auger.
60–110 in. B_{33}	Yellowish brown (10YR 5/7) silty clay with 10 to 20 mm thick zones of gray (N 7/0) clay increasing in number with depth; less firm than B_{32m}; no pebbles; well laminated; laminae 3 mm thick; neutral.
110–135 in. C	Yellowish brown (10YR 5/6) laminated silty clay with very dusky red (2.5YR 2/2) thin coatings on laminae; upper part has a few zones of gray as in B_{33}; no pebbles; calcareous, effervesces weakly; lower part of lacustrine material.
135–153 in. D_1 (A_b)	Yellowish brown (10YR 5/4) sand; neutral; boundary abrupt.
153–160 in. D_2 (B_{1b})	Strong brown (7.5YR 5/8) sandy loam; neutral; boundary gradual.
160–190 in. D_3 (B_{2b})	Yellowish brown (10YR 5/4) sandy loam with light brownish gray (10YR 6/2) mottles at 172 to 190 in.-depth; no pebbles; slightly acid.
190–240 in. D_4 (C_b)	Yellowish brown (10YR 5/4) loamy sand; slightly acid.

The morphology of this imperfectly drained soil is like that of other deeply weathered, imperfectly drained, Gray-Brown Podsolic soils, developed from water-laid material in the unglaciated part of Columbiana County. It has a distinct B horizon marked by clay accumulation, and the fragipan is weak. Fragipans in coarser textured, imperfectly drained soils are stronger.

The upper part of the solum at 0 to 42 in. is formed in an alluvial or lacustrine material which contains a few channers and small pebbles of local rocks at 22 to 42 in. The amount of channers increases in the upper part of this material as it extends toward the valley wall where it joins with the colluvium from upslope. The underlying part of the solum at 42 to 125 in. is formed in laminated lacustrine silty clay which apparently belongs to the same geological event because there is no paleosol between the upper and lower parts. The sandy material at 135 to 240 in. apparently belongs to a previous event as it has a palesool which was developed in its upper part and has a B horizon evident in both texture and color (table 2). The paleosol is more acid than the calcareous lacustrine mantle. Nearby this sandy material is not covered and here, a deeply weathered yellowish red soil is formed in it. The sandy material here, contains layers of gravelly glacial outwash and is like the material described on the Riverview Greenhouse

Terrace. The glacial outwash is underlain by 3 ft of an older very strongly acid lacustrine material not shown in figure 2. This material is being studied elsewhere and will be reported when study is completed.

About 800 ft northwest of Profile 3, at the foot of the valley wall (fig. 2, Profile 4), colluvium buries a lacustrine deposit two ft. thick which in turn lies over a mudflow.

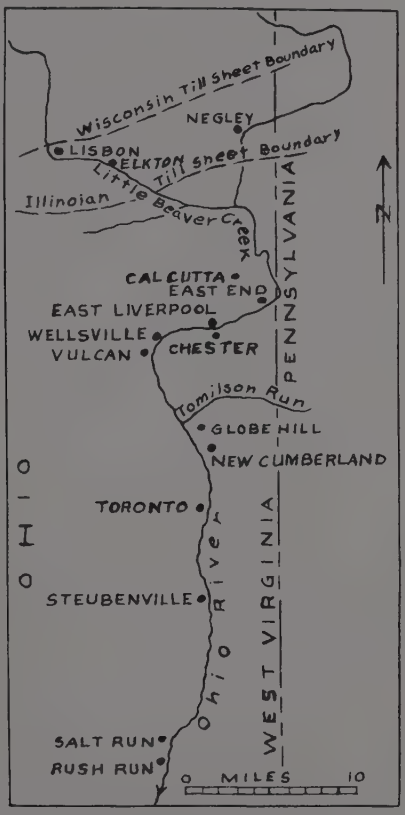

FIGURE 3. Map of Upper Ohio Valley.

The profile described here is located at the center of the NE¼ NW¼ Section 10, Yellow Creek Twp., along the west edge of Russel Heights in the foundation of the second house west of a small stream. The site is on a footslope of a steep valley wall, has a 12 percent slope and is at 970 ft elevation above sea level.

Profile 4.—Description of moderately well drained soil from colluvium over lacustrine silty clay over mudflow. (Described by W. H. Hale and H. D. Lessig)

Depth and Horizon	*Profile Description*
0–1 in. A_1	Very dark brown (10YR 2/2) silt loam; weak fine granular structure; channers 5%; very strongly acid; boundary abrupt smooth.
1–9 in.	Very dark grayish brown (10YR 3/2) silt loam; weak fine granular

A_2	structure; friable; channers 5%; very strongly acid; boundary abrupt smooth.
9–11 in. B_1	Yellowish brown (10YR 5/4) silt loam; moderate fine subangular blocky structure; friable to firm; channers 5%; very strongly acid; boundary abrupt smooth.
11–16 in. B_{21}	Light olive brown (2.5Y 5/4) channery coarse silty clay loam; moderate fine subangular blocky structure; thin dark grayish brown (10 YR 4 2) clay coats on ped faces; friable to firm; channers and fine pebbles 25%; very strongly acid; boundary abrupt smooth.
16–23 in. B_{22}	Brown (10YR 5 3) channery coarse silty clay loam with many fine faint reddish brown (5YR 4 4) mottles; moderate fine subangular blocky structure; thin reddish brown (5YR 4 4) clay coats on ped faces; firm; channers and fine pebbles 20%; very strongly acid; boundary abrupt smooth.
23–34 in. B_{23gm}	Finely mottled strong brown (7.5YR 5/6) and gray (10YR 5/1) channery silty clay loam to silty clay; fragipan with strong medium angular blocky structure breaking to strong fine angular blocky peds; 1 mm thick gray (N 5 0) clay coats on ped faces; more firm than B_{22}; channers and fine pebbles 20%; strongly acid; boundary clear; horizon is lower part of water worked colluvium.
34–40 in. B_{24gm}	Dark brown (7.5YR 4 4) silty clay with many medium distinct gray (N 5 0) mottles; fragipan with strong coarse angular blocky structure breaking to strong fine angular blocky peds; 3 mm thick gray (N 5 0) clay coats on ped faces; firm to very firm; pebbles 5%; strongly acid; boundary clear; horizon is upper part of lacustrine material, is poorly sorted.
40–48 in. B_{25gm}	Medium distinctly mottled dark yellowish brown (10YR 4/4) and gray (10YR 5 1) silty clay; fragipan with strong coarse angular blocky structure breaking to strong fine angular blocky peds; 3 mm thick gray (N 5 0) coats on ped faces; firm; channers and fine pebbles 5%; strongly acid; boundary clear wavy.
48–62 in. B_{26g}	Dark brown (7.5YR 4 4) silty clay loam with many coarse distinct gray (10YR 5 1) mottles, and 9 in. thick vertical zones of total gley; weak very coarse prismatic structure breaking to moderate fine angular blocky peds; 2 mm thick gray (10YR 5 1) clay coats on ped faces; less firm than B_{25g}; no pebbles, well sorted; medium acid; boundary abrupt smooth; horizon is lower part of lacustrine material.
62–108 in. D	Large irregular masses of olive brown (2.5Y 4/4) silty clay loam and dark reddish gray (5YR 4 2) silty clay with 1 mm thick vertical seams of gray (N 5 0) clay; massive; flat siltstone channers of local rocks 20%; neutral; unsorted mudflow, reported by builder to be very thick beneath the excavation.

Major morphological features of this soil are a fragipan at 23 to 48 in., gleying at 23 to 62 in., and a strong textural and structural B horizon. Fragipans are unusual in silty clay horizons. This fragipan was so identified because the soil material was firm in a moist condition and brittle. The thickness of gleyed materials is great but not unusual for unglaciated soils in positions where internal seepage is received from upper slopes. The 9-in. thick, vertical gley horizon at 48 to 62 in. is unusual but such has been found by the author in deep horizons of highly weathered soils formed in thick alluvium. A deeply weathered soil is formed in the colluvium which is evidence that this material is not a recent or current deposit. This moderately well drained soil is like other Gray-Brown Podsolic soils. It differs from well-drained soils developed in colluvium, nearby, in that they lack B horizons, marked by clay accumulation.

The upper part of the solum at 0 to 23 in. is formed in colluvium which has been reworked a little by water and is apparently part of the same soil mantle described at Profile 3, 800 ft to the southeast, though nearer the shore of the body of water. The lower part of the solum at 34 to 62 in. is formed in lacustrine material which is like but not as well sorted as the laminated lacustrine silty clay of Profile 3, but also formed nearer the shore. The mudflow material at 62 to 108 in. apparently is formed from bedrock on the valley wall which includes neutral red clay shale. No evidence of buried paleosols was found at Profile 4. Apparently the mudflow, lacustrine and colluvial deposition occured as a contemporaneous sequence of events taking place long enough after the deposition of the glacial outwash that a paleosol was formed in the glacial outwash at Profile 3 before it was buried.

DISCUSSION

Soils of the high terrace remnants as found on the Riverview Greenhouse and Vulcan terraces have varied morphologies. The soil forming processes causing some soils in close proximity to each other to have morphological characteristics of the Red-Yellow Podsolic group and others to have characteristics of the Gray-Brown Podsolic group are not readily explainable. Red-Yellow Podsolic-like Profile 1 is well-drained while other less well-drained profiles are like local soils classed as Gray-Brown Podsolic soils. It appears that soil forming processes may vary according to soil internal drainage.

Another possibility is that Profiles 2, 3 and 4 have some properties of moderately well and imperfectly drained Red-Yellow Podsolic soils which the author has not recognized.

All four of these profiles have been subject to various climatic regimes which have occured since very early or early Pleistocene time. This is a much longer and more varied period of time than post-Wisconsin time. Some of these climatic regimes were such that Red-Yellow Podsolic soils were formed according to Peltier (1949, p. 47). Red-Yellow Podsolic-like soils are found on local early Pleistocene glacial outwash such as at the corner of Pennsylvania Ave. and Blakley St. in East Liverpool (Lessig, 1959b, p. 336). Another paleosol buried beneath fresh Illinoian till near Elkton, Ohio has latosolic properties (fig. 3) (Lessig, 1959c). This limited evidence indicates a warm humid climate during pre-Illinoian time.

However, the reddish (5YR) hue, with high chroma, found in well-drained soils formed from early and very early Pleistocene glacial outwash in Columbiana County is not found in equally old, well-drained soils on the same high terrace level in the tributary vallies which did not receive glacial outwash. These non-glacial soils have a more yellowish color, in the 10YR hue. It is possible that the more mixed lithology of the glacial outwash is responsible for the redder colors in the well-drained soils.

A well-drained soil formed in very early Pleistocene water-laid silty material near Calcutta (fig. 3) (Lessig, 1960) has a Gray-Brown Podsolic upper solum but below 42-in. depth there are iron-cemented-sand fragments and yellowish red soil material. I think that, here, a Gray-Brown Podsolic Soil is formed in a former Red-Yellow Podsolic Soil.

This sort of a soil forming process is reasonable under past and present climatic regimes. I am not prepared at present to form a suitable hypothesis for the differences of these various soils on the high terraces. It is hoped that further soil mineral and pedo-geological studies will lead to an elucidation of the Pleistocene history and the nature of the soils in the upper Ohio Valley.

The gravelly material of the Riverview Greenhouse Terrace is very deeply weathered, having structure to a 108–in. depth, firm consistence to 120 in., strong acidity to over 204 in., and the pebbles above the 204-in. depth, except those of quartzite, are rotted so that they crush in the fingers when rubbed. The pebbles in the silty and sandy material of the Vulcan Terrace are less weathered. A

reason for this could be that the Vulcan site is only 150 ft from the terrace escarpment while the Riverview Greenhouse site is 500 ft from a dissecting ravine and is separated from the entrenched portion of the Ohio Valley by bedrock hills. Some of the upper soil material of the Vulcan site may have been removed by geological erosion because of its proximity to the terrace escarpment.

The pebbles of the Riverview Greenhouse and Vulcan terraces are weathered to a greater degree than those of the 850-ft terrace, remnants of which are found just north of the supermarket in East End, at the Corner of Pennsylvania Ave. and Blakley St. in East Liverpool (Lessig, 1959b) and at Globe Hill, W. Va. (Lessig, 1959a).

The glacial outwash of the Riverview Greenhouse and Vulcan terraces was deposited over preglacial stream levels which probably are a little lower than given by Leverett, and Stout, VerSteeg and Lamb (1943) because the rock floor of the Vulcan Terrace is below 960 ft at Profile 3. There is a lacustrine material beneath the glacial outwash at Hamond Park.

The very early and early Pleistocene sequence of events which deposited the varied soil materials on the Vulcan Terrace occured in two well separated stages because a paleosol was formed in the glacial outwash before it was buried by the lacustrine material at Profile 3. The arrangement of materials at Hammond Park and Russel Heights suggests the following sequence of events there: deposition of sandy and gravelly outwash over pre-glacial terrace levels; intrenchment of the outwash near the valley wall and soil formed in the outwash; mudflow from the valley wall deposited in part of the intrenchment; rise of water, burying the mudflow and part of the outwash with lacustrine material to 960 ft; deposition of colluvium along the valley wall and moving water conditions which reworked some of the colluvium which entered the body of water, depositing channers in the lacustrine material. All of these events must have preceeded the deposition of a less weathered glacial outwash at 830 ft at Globe Hill, 6 miles downstream.

At Globe Hill a gravelly glacial outwash was deposited over two stages of alluvial deposition over bedrock at 800-ft elevation. The events predating the 830-ft outwash at Globe Hill and postdating the 1020–960-ft outwash at Vulcan and the Riverview Greenhouse are not correlative. This suggests a long interglacial period and several geologic events between these two glaciations of the Allegheny Plateau.

Lower glacial outwash terrace levels at 760 and 720 ft near East Liverpool have less weathered soil materials and can be traced northward along Little Beaver Creek (fig. 3) to the Illinoian and Wisconsin till sheet boundaries. These terraces and their soils are under study and will be reported when their study is completed.

CONCLUSIONS

The well-drained soils, developed over gravelly glacial outwash, of the high terrace remnants at the Riverview Greenhouse and Vulcan have some properties of Red Yellow Podsolic soils while the soils with slower drainage are like the soils classed as Gray-Grown Podsolic soils which are normal to Columbiana County.

The glacial outwash of these terrace remnants belongs to the first glaciation of the Allegheny Plateau because it is the highest, most deeply weathered, in the upper Ohio Valley and is deposited over preglacial stream levels.

Lacustrine and colluvial deposits are also found on the high terrace remnants. They are attributed to other geological events. These preceded other geological events described at Globe Hill, West Virginia, in a preceding report. One layer of lacustrine material is older than the outwash of the first glaciation.

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Conservation of Natural Resources. *Guy-Harold Smith*, Editor and Contributor of Five Sections. Eighteen other authors. 2nd edition. John Wiley & Sons, Inc. xi+474 pp. $8.50.

The first edition of this book was published in 1950, shortly after the end of World War II when its timeliness was associated with the war's wasteful use of natural resources. Then began the program of foreign aid and the world-wide scattering of more of our resources, with quantities lost in Korea. Finally, there is the present race with Russia, and the adequacy of natural and human resources for this ruthless race for power is the subject of great concern.

The editor has selected experts in the many phases of conservation and the compendium is authoritative as well as informative and interesting. If gauged by its importance to well-read citizens, this book renders invaluable service. It is well illustrated, well documented, and well indexed, so readers may select subjects for study without extending beyond their needs for reference on special aspects of the subject matter. College students should read it cover to cover, and thus qualify themselves to serve as better leaders of the country during the coming critical decades.

THOMAS H. LANGLOIS

Structural Methods for the Exploration Geologist. *Peter C. Badgley.* Harper & Brothers, New York. 1959. xv+280 pp. $7.50.

Methods of geologic illustration by means of controlled diagrams, maps, and cross-sections are explained with the help of numerous illustrations. Following the explanation of each technique or device is a series of problems that illustrate it. The problems are clearly set out and well illustrated; maps and aerial photos suitable for each problem are included in the book. Completion of a selection of the problems would be of great help to the student of structural geology. In addition, any geologist will find inspiration here concerning methods of resolving and illustrating geologic data of his own. The examples cited and the problems offered come largely from economic geologic deposits, areas or provinces. Thus the training provided the student has a direct bearing on the sorts of professional problems with which he may later need to deal.

MALCOLM P. WEISS

SOME PRELIMINARY OBSERVATIONS ON MOSQUITO LARVAE AND PUPAE CONFINED TO A BOTTOM AIR-WATER INTERFACE†

ROGER MEOLA

Department of Zoology and Entomology, The Ohio State University, Columbus 10

During October and November, 1960, two species of *Aedes* mosquitoes [*Aedes aegypti* (L.) and *Aedes triseriatus* (Say)] were reared from first instar larvae to adults in an inverted position. This was accomplished by restricting the larval and pupal stages to a downward, rather than upward facing, air-water interface. Such an interface was obtained by inverting 10 by 75 mm culture tubes which remained completely filled with water after inversion because of air pressure, so that the only source of air available to the mosquitoes was at the bottom interface. Each tube has a capacity of about 3 ml.

As shown in figures 1 and 2, both the larvae and pupae assume positions exactly reversed from those which they assume under normal conditions. Since it has been fairly well established that the immature stages exhibit a negative geotropism when attempting to obtain air, I was quite surprised that they were able to overcome this influence and to adjust eventually to this up-side-down orientation.

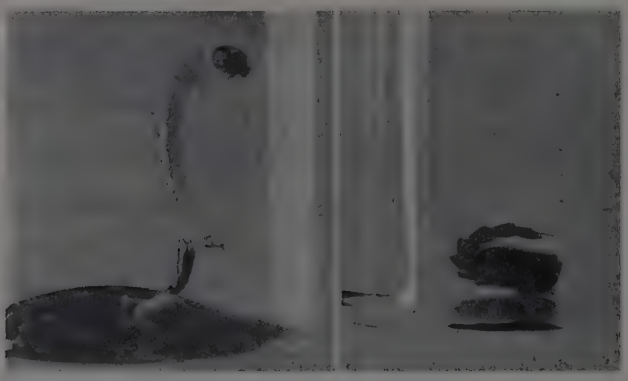

FIGURE 1. (Left) *Aedes* larva obtaining air from a bottom interface.
FIGURE 2. (Right) *Aedes* pupa obtaining air from a bottom interface.

It was also interesting to note that larvae are capable of adjusting to this bottom interface even after several days of normal rearing, but the pupae seldom survive if subjected to a bottom interface after being reared to this stage in an upright position.

Two other observations may be cited at this time. First, *Aedes* larvae normally obtain food from the bottom sediment. In the inverted position feeding is often carried on at the bottom interface during respiration. Second, several individuals were observed emerging successfully through the bottom interface although mortality was fairly high. Those which emerged as adults appeared to behave normally.

†Supported by a grant from the National Institute of Health supervised by D. M. DeLong, Ohio State University.

DECENTRALIZATION OF THE AKRON RUBBER INDUSTRY

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The growth of the rubber industry is reflected in the development of the Akron area as the major center of rubber manufacturing in the United States. Until recently, the Akron rubber companies manufactured half of the nation's tires as well as a large part of all the other rubber goods. Harold McCarty (1940) states, "It is difficult to find a city more highly specialized in the manufacture of a single product."

However, since 1929 when the greatest concentration occurred, there has been a relative decline in the proportion of the industry located in the Akron area. Recent Census of Manufactures data for 1954 show that Akron had only 3.3 percent of the total number of establishments in the industry and 17.6 percent of the total number of production workers (table 1). In the tire and tube divi-

TABLE 1[1]

Relative part of the United States rubber industry concentrated in the Akron area, 1954 (Money figures in thousands of dollars)

Industry Division	Akron area Total	Akron area Percent	United States Total
Tire and Inner Tubes:			
No. of Establishments	6	12.2	49
No. of Employees	34,611	37.3	92,748
Production Workers	26,117	35.3	73,976
Value Added by Mfg.	211,125	24.9	844,545
Rubber Products: (Not elsewhere classified)			
No. of Establishments	37	2.8	1,315
No. of Employees	10,229	7.7	132,503
Production Workers	7,626	7.3	104,028
Value Added by Mfg.	73,933	7.9	930,086
Total Rubber Products			
No. of Establishments	47	3.3	1,406
No. of Employees	45,930	18.6	246,526
Production Workers	34,660	17.6	196,237
Value Added by Mfg.	294,030	15.4	1,903,701

[1]U. S. Bureau of the Census, Census of Manufactures, 1954: Vols. II and III, (Washington: Government Printing Office, 1957).

sion, Akron's share in 1954 was greater with 12.6 percent of the total number of establishments and 35.3 percent of the total number of production workers in this division (table 1).

The purposes of this paper are to note some of the changes which have occurred in the concentration of rubber manufacturing in the Akron area and to examine several of the factors which have influenced the decentralization of the industry. In this study, the Akron area includes the territory within the corporate limits and immediate environs of the cities of Akron and Barberton, Ohio, which are contiguous.

Period of Concentration, 1921 to 1929

The concentration of the rubber industry in the Akron area occurred chiefly during the period from 1921 to 1929. Using the number of production workers as a measure of manufacturing, these data show that Akron's share of the rubber industry increased constantly during this period (table 2). In 1921 the Akron rubber factories employed 22.9 percent of the total production workers in the rubber industry in the United States. By 1925 Akron's share of the total production workers had increased to 31.7 percent. The greatest concentration of the industry occurred in 1929 when the Akron rubber factories employed 35.6 percent of the total production workers in rubber manufacturing.

The concentration of rubber manufacturing from 1921 to 1929 appears to have been due largely to the cumulative advantages of an early start, growth in scale of operations, and a favorable market location. With three of the "big four" tire companies in the area, Akron was the center of competition in the rubber industry and here was found the leadership in introducing innovations in methods and machines. The "big four" tire companies include the United States Rubber Company, Goodyear Tire and Rubber Company, B. F. Goodrich Company, and Firestone Tire and Rubber Company. The home offices and major manufacturing

TABLE 2[1]

The number and percentage of production workers in the rubber industry in the United States and in the Akron area for selected years

Year	Akron area		United States
	Number	Percent	Total number
1921	23,697	22.9	103,273
1923	36,578	26.5	137,868
1925	44,757	31.7	141,121
1927	45,495	32.0	141,979
1929	53,172	35.6	149,148
1933	32,000	30.1	106,283
1937	37,419	28.8	129,818
1939	30,579	25.3	120,740
1947	49,813	23.2	214,533
1954	34,660	17.6	196,237

[1]The Census of Manufactures for the years given.

plants of the latter three are located in Akron. An indication of the increasing scale of operations and the competitive strength of the plants in Akron was noted in the decline in the number of tire and tube plants throughout the country. In 1921 there were 178 tire and tube establishments in the United States, but by 1929 the number was only 91 plants, with 14 located in Akron. Rubber factories concentrated in the Akron area were well situated to minimize transportation costs on finished products by being near the original equipment market and in the heart of the tire replacement market.

During the period from 1920 to 1929, some dispersion of the rubber industry to locations outside the Akron area occurred as a result of the re-location of one of the large tire companies and the erection of branch facilities by the other tire companies in Akron. In 1920, the Kelly-Springfield Tire Company wanted to expand its facilities but its physical plant in Akron was nearly surrounded by the Goodyear plants. As a result, the company relocated its entire plant facilities in Cumberland, Maryland, in an effort to be near the luxury tire market in the East which it supplied. The Kelly-Springfield Tire Company declined in its new

location until 1935 when controlling interest was purchased by the Goodyear Tire and Rubber Company.

In the same period, other Akron rubber companies erected branch plants at locations outside Akron (table 3). In 1920 the Goodyear Tire and Rubber Com-

TABLE 3[1]

The location of the major branch plants of the Akron area companies in the United States during the period 1920–1958

Parent Company	Branch Plant Location	Year Established	Products Manufactured
Goodyear Tire and Rubber Company:	Los Angeles, Cal.	1920	tires
	Gadsden, Alabama	1929	tires
	Cumberland, Md.	1935	tires and tubes
	Windsor, Vermont	1936	heels and soles
	Jackson, Michigan	1937	tires
	St. Marys, Ohio	1939	mechanical goods, pliofilm
	Lincoln, Nebraska	1943	industrial rubber goods
	Muncie, Indiana	1943	tread rubber, brake lining
	New Bedford, Mass.	1943	bicycle tires
	Topeka, Kansas	1943	farm and truck tires
	N. Chicago, Ill.	1955	rubber hose
	Chevalis, Wash.	1957	tread rubber
B. F. Goodrich Company:	Los Angeles, Cal.	1928	tires and latex
	Watertown, Mass.	1930	footwear and flooring
	Cadillac, Mich.	1937	industrial rubber products
	Oaks, Penn.	1937	tires
	Clarksville, Tenn.	1939	soles and heels
	Miami, Oklahoma	1943	tires
	DuBois, Penn.	1945	golf ball centers
	Riverside, N. J.	1945	latex supplies
	Tuscaloosa, Ala.	1945	tires
	Troy, Ohio	1947	products for aircraft interiors
	Marietta, Ohio	1950	Koroseal materials
	Marion, Ohio	1950	industrial products
	Derby, Conn.	1954	sponge rubber products
	Shelton, Conn.	1954	sponge rubber products
	Greenville, Ky.	1957	footwear and flooring
	Exeter Borough, Pa.	1958	tire cord
Firestone Tire and Rubber Company:	Los Angeles, Cal.	1927	tires
	Fall River, Mass.	1937	mechanical goods
	Memphis, Tenn.	1937	tires
	Noblesville, Ind.	1937	mechanical goods
	Newcastle, Ind.	1942	mechanical goods
	Pottstown, Penn.	1943	tires
	Des Moines, Iowa	1945	tires
	Magnolia, Ark.	1954	defense products
	Quincy, Ill.	1957	fabricated products
General Tire and Rubber Co.:	Wabash, Ind.	1937	mechanical goods
	Waco, Texas	1943	tires
	Jeanette, Penn.	1945	athletic goods, plastics
Seiberling Rubber Company:	Carey, Ohio	1950	heels and soles
	Newcomerstown, Ohio	1954	plastics

[1]The above list does not include synthetic rubber plants, plants making non-rubber products, foreign branch plants, and branch plants supplying materials to the Akron area plants.

pany set up a tire assembly plant at Los Angeles, California. The Firestone Tire and Rubber Company and the B. F. Goodrich Company established branch plants in the Los Angeles area in 1927 and 1928, respectively. The Pacific Coast area was becoming a market of sufficient size to allow economical operation there of large rubber plants and direct shipment of crude rubber was cheaper. In 1929 the Goodyear Company built a plant at Gadsden, Alabama, to meet the demands of the Sears Roebuck and Company for a plant to serve its southern market.

Continued Concentration during the Depression Years, 1930 to 1935

During the depression years, 1930 to 1935, Akron maintained a proportional share of the total rubber industry comparable to the preceding period. The rubber companies in the Akron area had secured the advantages of concentration by 1929, and as a result were in the best financial position when demand declined with the world-wide depression in the 1930's. They were financially able to sustain losses from operations below capacity and large frozen inventories. Other companies were not so fortunate because of less favorable locations and less efficient scale of operations. The result was the continued concentration of rubber manufacturing in the Akron area without much change in locational factors between 1929 and 1935. The major factories tending toward decentralization were not effective until the markets began to increase in 1936.

Decentralization of the Akron Rubber Industry, 1936 to 1939

The greatest movement in rubber manufacturing from the Akron area occurred after 1935 following the renewed growth in demand. In 1935 the Akron area had approximately 30 percent of the total number of production workers in the rubber industry, but by 1939 it had a smaller proportion of workers than at any-time in the preceding 15 years (table 1). In 1939, Akron's share of the production workers had dropped to 25.3 percent, a loss of nearly 5 percent in four years.

This loss of rubber manufacturing resulted from the erection of new branch plants and from the increase in output of existing branch factories. Many branch plants were established by the Akron rubber companies after 1935 (table 3). The Goodyear Company constructed a tire factory at Jackson, Michigan, in 1937, and expanded capacity at its Gadsden and Cumberland plants. The Firestone Company erected a new plant in Memphis, Tennessee, in 1937; and the B. F. Goodrich Company built a new tire plant at Oaks, Pennsylvania, in the same year.

After 1935 the Akron tire companies began to move their production of mechanical and other rubber products to new locations outside of Akron. The production of these items requires less skilled labor than tire production, value of output is lower, and a larger proportion of the total costs of these products than tires, it appears that the movement was to areas of lower labor costs. All the major tire companies in Akron established plants and facilities elsewhere to produce mechanical and other rubber products after 1935 (table 3). The movement of this type of production was so substantial that by 1938 B. F. Goodrich was the only tire company producing a considerable proportion of nontire products in Akron. By 1954 the Akron area had only 7.7 percent of the total number of production workers engaged in manufacture of rubber products other than tires, and the output of rubber footwear was insignificant (table 1).

Various reasons for decentralization of the Akron rubber industry after 1935 have been noted in studies of the tire and tube industry. Gaffey (1940) suggests that the significant movement of the rubber industry was due to the unfavorable position of the Akron area with regard to labor costs and labor relations. He points out that wage rates in Akron area were 40 to 50 percent higher in 1938 than in other areas of the United States. The indications are that the Akron rubber companies put through these wage increases in an effort to halt the growth

of unionism. Gaffey further notes that the growth of the rubber worker's union in Akron has strengthened the tendency for the rubber industry to decentralize. In both the 1933–34 and the 1936–37 organizing campaigns, the greatest efforts of the union leaders were concentrated in the Akron area. Similarly, the Akron rubber companies were the most vigorous opponents of unionism. The result was a bitter labor-management struggle in which the union made considerable gains by 1938. Gaffey concludes that the concentration of union strength in Akron gives the rubber plants there an unfavorable competitive situation and this remains a factor favoring further decentralization. Although the above factors were important in the movement of the rubber industry out of the Akron area after 1935, it appears that decentralization had started before the labor struggles and the rise of unionism (table 3). The labor struggle merely increased the rate of an earlier trend.

Probably more significant than wage differentials and labor unions in affecting decentralization of the industry have been the technological developments and changes in market areas. Technological developments have offset the advantages of centralized mass production which affected the location of production until 1929. According to Akron rubber officials, scale of operation stopped growing about 1929 when the Banbury mixer came into general use. This machine sets the minimum economic scale of operation. These developments gave a small rubber plant advantages in process alignment, continuous flow of materials, groundfloor operations and mass production which allowed it to compete with plants having several times the capacity. Since 1935 the demand for rubber products has been growing continuously and market areas have developed in which local demand is adequate for the economical operation of a small but efficient plant. Since rubber manufacturing is essentially an assembly industry and is, therefore market oriented, branch plants of the Akron rubber companies have been established within individual market areas outside Akron in order to minimize transportation and other marketing costs.

World War II Developments in the Akron Rubber Industry

The period of World War II was one of major growth and change in the Akron rubber industry. Plant capacities and mass production techniques were converted to war-time productions. Unused plant facilities were adapted to the new production changes and plant expansions were made to meet the increasing demands of the military. Three synthetic rubber plants were built in the Akron area following the loss of our crude rubber sources in southeastern Asia. New rubber products and rubber derivatives were developed such as foam and sponge rubber, together with new trade-name products such as Koroseal, Pliofilm, and Vinyl. Chemical and plastic production has continued to the present time as one of the major trends in the diversification of the rubber industry.

During the war years, plant expansions outside the Akron area were based primarily on labor supply and government support. Important new plant expansions were made by: (1) Firestone at Pottstown, Pennsylvania, and Des Moines, Iowa; (2) Goodyear at Topeka, Kansas; (3) Goodrich at Miami, Oklahoma, and Tuscaloosa, Alabama, and ; (4) General at Waco, Texas (table 3). Although these plants were not located for the usual economic reasons, their establishment has affected the relative concentration of the rubber industry since the Akron companies bought them from the government at a price which allows profitable operation today.

Another major war change in the Akron industry was the tremendous expansion in the production of mechanical and rubber products other than tires. In 1939, 16 companies were manufacturing these products in the Akron area, but in 1947 the number had increased to 27. In the same period the number of production workers in the plants manufacturing these items increased from 1,700 to more

than 3,500, an increase of over 105 percent. This phase of the manufacture of rubber has continued as an important part of the rubber industry in the Akron area to the present time.

Post-war Developments in the Akron Rubber Industry

Following the close of World War II, peace time demands stimulated the market for tires, tubes, and other rubber products which were scarce during the war years. The Akron companies met the post-war demands by expanding their productive capacity in local and branch plants in operation at the end of the war. The rubber companies continued to operate at or near capacity through 1947 when supply finally began to exceed demand. As a result, total rubber employment in the Akron area dropped sharply. However, the outbreak of the Korean War stimulated a sharp increase in rubber production, and by 1951 employment had increased to near-peak levels.

More recent developments of the Akron rubber industry have been: (1) a continued decline in the relative concentration of rubber manufacturing due to the erection of branch plants and growth of competitive producing area; (2) an increasing trend in the diversification of production with emphasis on plastics and chemical derivatives, and; (3) a lessening of government control of rubber supplies and prices.

Conclusions

The Akron area was still the major center of the rubber industry in the United States in 1957. Although Akron's share of the nation's rubber production has continued to decline since 1929, the local rubber factories employed more than 17 percent of the total production workers and produced the major part of tire and tube output. In the production of rubber footwear, reclaimed rubber, and other rubber products, the Akron area has lost a considerable proportion of the total production There is no evidence to show an absolute decline in rubber manufacturing in the Akron area, but the growth of the industry in other areas indicates an inevitable decline in the former concentration of the industry. This does not mean regression for the rubber industry in the Akron area but merely a change in its relative importance as the center of production within the United States.

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THE ABRI SCHMIDT, AN IMPORTANT UPPER PALAEOLITHIC SITE IN BAVARIA

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INTRODUCTION

The excavations reported upon in this paper were undertaken during the summer of 1959 as part of a joint project of the Cleveland Museum of Natural History and the Prehistoric Institute of Erlangen University, with the principal aim of carrying out an extensive survey of prehistoric remains in the lower Altmühl Valley, Bavaria, near the confluence of that river and the Danube (Prufer, 1959). In the process of the survey, excavations were carried out at several prehistoric sites. The most important of these, a rock shelter which yielded remains of an Upper Palaeolithic encampment, forms the subject matter of this report.

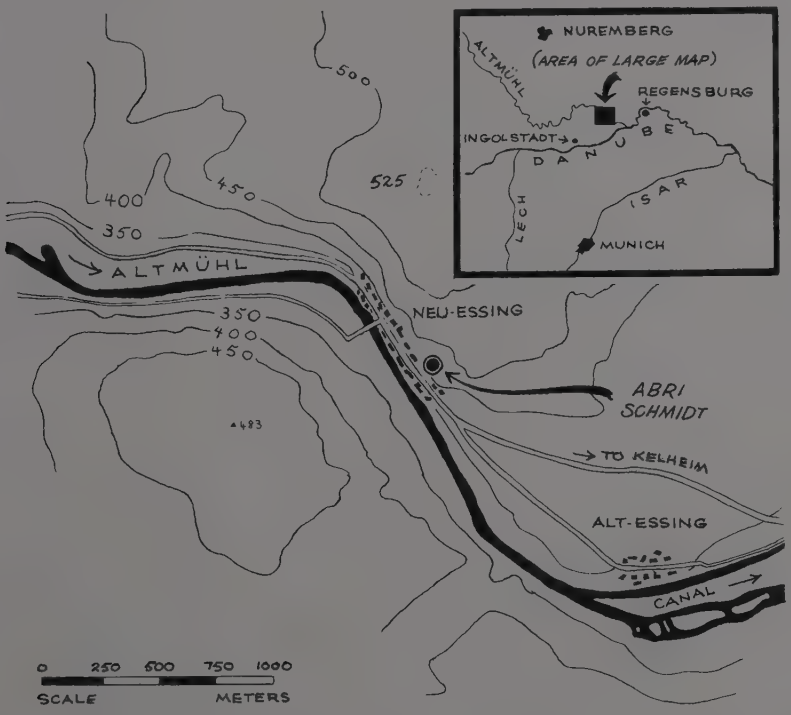

FIGURE 1. Map of the lower Altmühl Valley, Bavaria.

I wish to thank the following for their collaboration: Drs. Lothar F. Zotz and Gisela Freund of Erlangen University; Mr. Frank Davis, formerly of the University of California; and the staff of the Cleveland Museum of Natural History.

HISTORY OF PREVIOUS RESEARCH

The lower Altmühl Valley, especially the region of Neu-Essing, is well-known for its prehistoric remains. During the early decades of this century, a number of caves located in this area were systematically excavated (Birkner, 1916; Obermaier and Wernert, 1914). The results of these investigations gave clear and ample proof of the Altmühl Valley's importance for the study of the earliest prehistory of Central Europe. Thus, the Klausen caves at Neu-Essing not only yielded an entirely new early Stone Age assemblage, the so-called Lower Palaeolithic industry with leaf-shaped points (Obermaier and Wernert, 1929), which opened new avenues of research, but these caves also yielded remains of palaeolithic man's artistic endeavours which are notoriously rare east of the Rhine (Obermaier and Fraunholz, 1926, 1927).

During the period between the end of World War I and the present day, little systematic work has been carried out in the Altmühl Valley. Certainly, as of the end of World War II, the excavations reported upon here are the first serious attempt at unraveling the Stone Age history of the area.

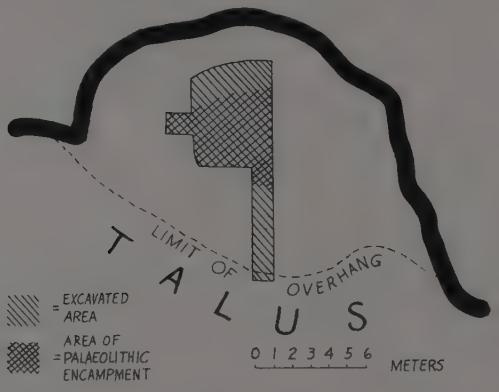

FIGURE 2. Plan of *Abri Schmidt* and excavations.

THE SITE

The site of the excavations, a rock shelter, has been named after its owner, the *Abri Schmidt*. It is located in the steep and picturesque limestone cliffs on the left bank of the Altmühl River, within the confines of the Village of Neu-Essing. The entrance to the shelter is situated about 30 feet above the level of the river.

Though many other caves and rock shelters in the immediate vicinity would have been suitable for excavation, the *Abri Schmidt* was chosen because its owner, digging an air raid trench at the shelter entrance during the war, had come upon evidence of a Stone Age encampment. Thus, the presence of a human occupation layer was assured, as well as the approximate depth at which the occupational level may be encountered.

Initially, a trial trench, measuring 1.25 x 12.00 meters was laid out at a right angle from the back wall of the shelter to the limit of the talus. Subsequently, after the main occupational level in situ had been encountered, the size of the trench was increased as indicated on the plan (fig. 2).

GEOLOGY

The following is an analysis and tentative interpretation of the stratigraphic record of the site.

It was found that toward the rear of the Abri all deposits lay horizontally from the surface down to bed rock. At the 3.5-meter mark from zero (fig. 3), layers D, C_1, and E_1 begin to dip at a steep angle toward the valley. At the 5-meter mark, this dip levels out to continue more or less horizontally as far as layer E_1, and slightly rising as far as layer C_1 is concerned. Interpolated between them was found layer F_3. At a distance of 11.00 meters from zero, the dip of these layers is resumed. The upper levels now also dip sharply toward the valley, the whole forming the talus slope.

The stratigraphic sequence may be summarized as follows:

A Loosely packed angular limestone débris and black humus, associated with medieval pottery, glass, nails and other iron objects.

B_1 Tightly packed, small angular limestone fragments mixed with considerable quantities of light gray-to-yellow sandy material.

B_2 Tightly packed, small angular and subangular limestone fragments mixed with considerable quantities of brown, sandy material. Many limestone fragments are covered with sinter.

B_3 Same as B_2.

B_4 Same as B_2.

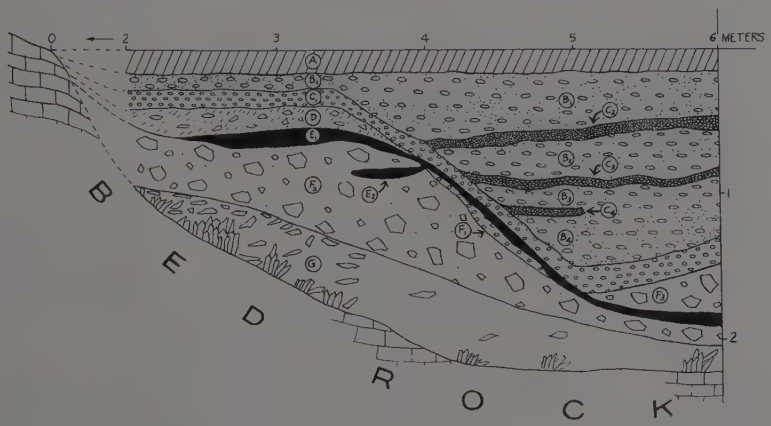

FIGURE 3. Stratigraphy of the deposits in the *Abri Schmidt*.

C_1 Loosely packed, somewhat coarse, angular limestone fragments. No matrix material.

C_2 Loosely packed, small angular or subangular limestone fragments mixed with very small amounts of grayish-brown sandy material. Some limestone fragments are sinter-covered.

C_3 Same as C_2.

C_4 Same as C_2.

D Medium tightly packed, coarse subangular limestone fragments mixed with considerable amounts of yellow-brown sandy material.

E_1 Culture layer. Sharply defined ochre-colored zone of angular limestone fragments mixed with ochre-colored sandy material, artifacts, bones, charcoal, etc.

E_2 Same as E_1; apparently was interpolated in F_2 when the whole horizon began to slip down toward the valley.

F_1 This layer is essentially similar in composition to C_1. At first it was thought to be part of that level, accidentally split apart by the interpolation of E_1. Such splitting, however, does not seem an adequate explanation, since E_1 shows no signs of disturbances, which alone could have explained why F_1 (had it been part of C_1) should have come to rest *beneath* E_1. Hence, it seem wiser to consider F_1 a separate unit, older than E_1.

F_2 Loosely packed, large and medium-sized angular limestone fragments, partly covered with sinter. Very little matrix material.

F_3 Very similar to D, but the limestone débris is larger.

G Very large angular limestone fragments, often covered with sinter and mixed with some rather coarse matrix material. This level represents the zone of limestone disintegration above the floor of the rock shelter.

The geological interpretation of this section is not easy. Further excavations and a sedimentary analysis now in progress will, no doubt, clarify some of the problems raised by the profile published here.

One thing is immediately apparent. The profile can be divided into two major phases. The older one comprises levels C_1, D, E_1, E_2, F_1, F_2, and G – in short, all those horizons which are involved in the earlier dip toward the valley bottom. The younger phase comprises levels A, B_1, B_2, B_3, B_4, C_2, C_3, and C_4, i.e., the top levels and those beneath, which form the infill subsequent to the dip.

The section would be relatively simple, were it not for the lenticular deposit F_1, and layers D and F_3, the appearance of which appears to be connected with the slipping involved in the dip. The stone industry found in layers E_1 and E_2 permits two possible interpretations. On the one hand, it may represent an early phase of the Central European Magdalenian; on the other hand, the industry may be part of a late Aurignacian horizon. The absence of characteristic Magdalenian bone tools does not lend much support to the Magdalenian interpretation. There are, however, as will be shown below, a number of ties between the industry of the *Abri Schmidt* and the so-called late Eastern Aurignacian.

How does the archaeological picture fit the geological evidence?

Assuming for a moment that the stone industry belongs into the Magdalenian, it would be difficult to explain the well-differentiated sequence of the layers above E_1, especially those forming the infill of the dip.

If, however, the industry belongs into the late Aurignacian, the geological sequence above E_1 might be easier to explain. In the first place it may be assumed that at least some time must have elapsed between the dip and the accumulation of the infill. This is especially suggested by levels D and F_3 which appear to be only partially present; it is at least possible that erosion was responsible for the disappearance of the bulk of these levels at a time when they were exposed to weathering.

Admittedly this interpretation of the section is tentative, but the nature of the profile, and the supporting archaeological evidence render it at least possible, if not probable. If this reading of the geological record is correct, the deposition of E_1 must fall into some phase, probably a very late one, of the Würm II/III interstadial. The infill of the dip would thus represent the Würm III stadial.

THE STONE INDUSTRY

The stone artifacts from the *Abri Schmidt* are puzzling. They represent a single industry which was recovered from level E_1. The small pocket labeled E_2 yielded only a few flint chips, some fragmentary bones, traces of charcoal, and burnt earth.

The artifacts are made of two types of flint. More commonly tabular flint occuring in the local limestone deposits was used. To a certain extent, the tabular nature of this raw material influenced the shape of the tools. In addition, flint pebbles from the nearby Danube gravels were fashioned into tools.

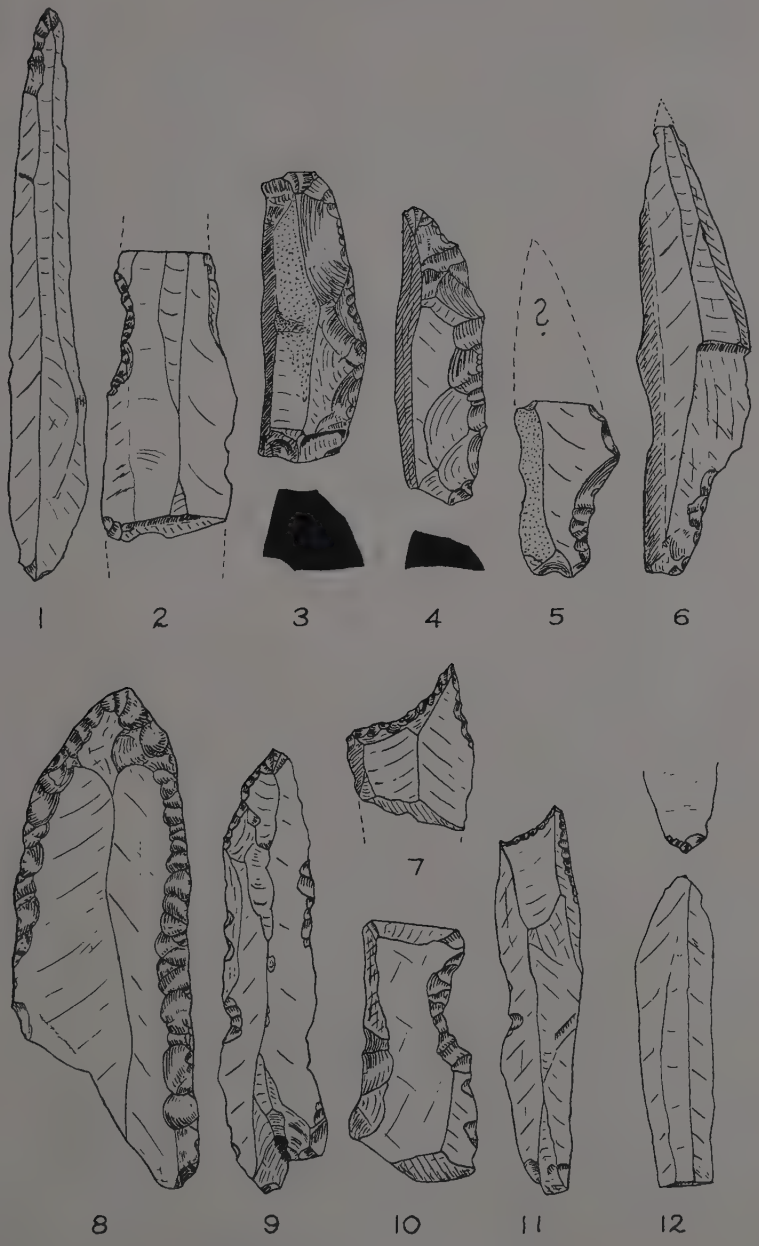

FIGURE 4. Artifacts from the *Abri Schmidt*.

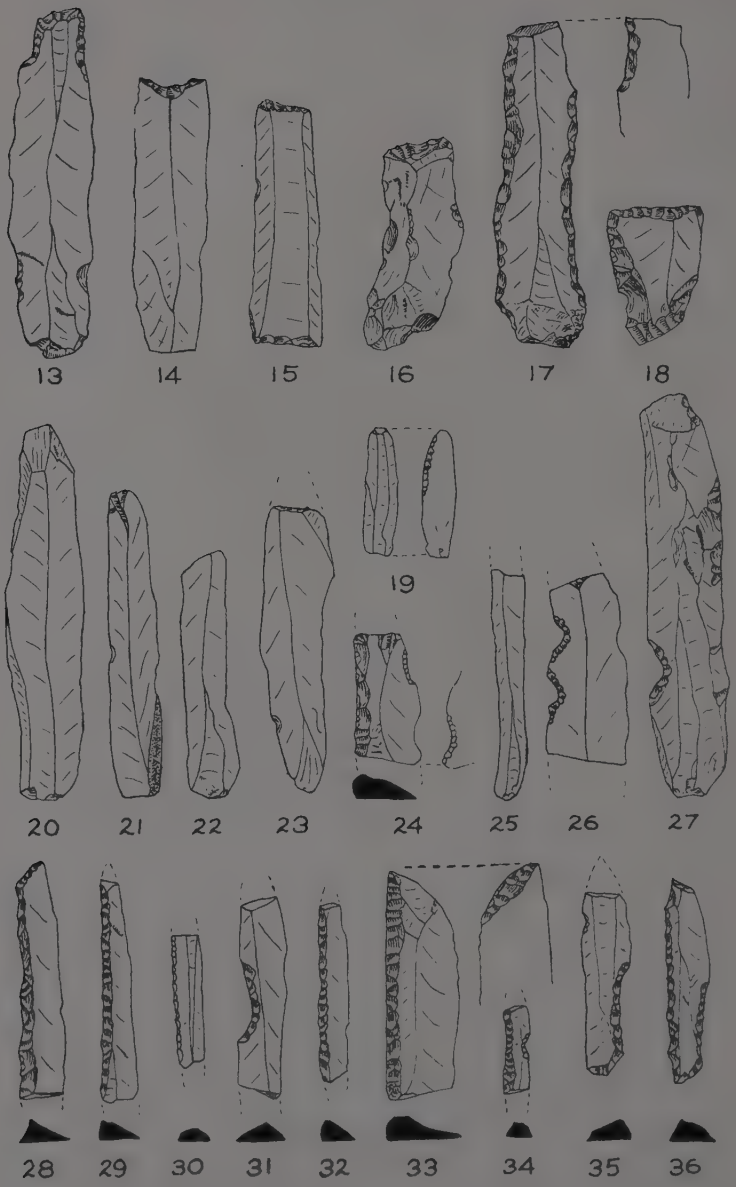

FIGURE 5. Artifacts from the *Abri Schmidt*.

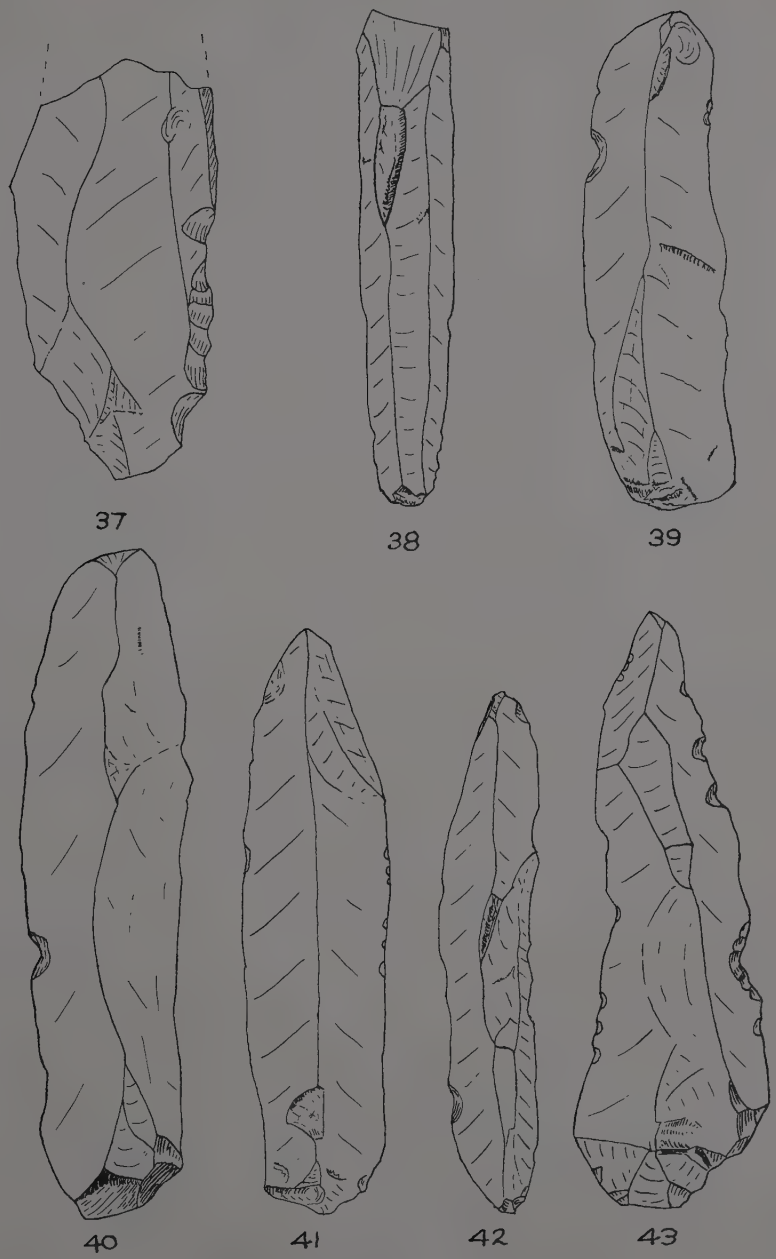

FIGURE 6. Artifacts from the *Abri Schmidt*.

The industry presents characteristics reminiscent of both the Magdalenian and late Aurignacian of Central Europe. Eastern influences are clearly discernable. The following is a typological analysis of the Industry:

1. *Plain blades.*—367 specimens. These are all typical Upper Palaeolithic blades. They are well-made and narrow, grading into micro-forms not exceeding 4 cm in length (fig. 5: 20–23, 25; fig. 6: 37–43).
2. *Retouched blades.*—19 specimens. With few exceptions, all of these blades are poorly retouched. Heavy marginal and nibbled retouch are represented. Consecutive retouch flaking is rare (fig. 4: 4). One specimen is retouched on the lower face (fig. 5: 19). Another is a finely worked blade, delicately retouched over the entire length of one side, and one-half of the other side on the upper face; this side continues to be retouched on the lower face (fig. 5: 17). Two specimens show continuous heavy marginal retouch terminating in a pointed end suggesting a characteristic Late Aurignacian type (fig. 4: 8).
3. *Pointed blades* 9 specimens. These are long, slender blades with unilateral or bilateral retouch, forming sharply pointed working ends (fig. 4: 1, 9; fig. 9: 61).
4. *Notched blades* 12 specimens. This series includes blades of all sizes. Several specimens show multiple small notches suggesting that they were used as saws (fig. 5: 26). Others have large notches. All except one are unilaterally notched (fig. 4: 2; fig. 5: 27, 31). The exception is a bilaterally notched blade reminiscent of a strangulated blade, albeit a poor one (fig. 4: 10).
5. *Backed blades*—10 specimens. These tools are steeply backed in the Gravette tradition. They are delicately worked and rather small. Six specimens are worked from the lower face, four from both faces (fig. 5: 28–30, 32).
6. *Backed and notched blades*—2 specimens. Both specimens are very small. One has a tiny notch (fig. 5: 34), the other has two notches, alternately flaked from the upper and lower faces (fig. 5: 24).
7. *Backed blade with oblique ventral "capping" retouch*—1 specimen. This delicately worked type (fig. 5: 33) occurs characteristically in the Gravettian (Périgordian 5) of France.
8. *Blades with terminal shallow ventral retouch* 5 specimens. This type has essentially an eastern distribution. It belongs into the late Aurignacian of the East (fig. 4: 12). It occurs profusely at Predmost in Czechoslovakia (Zotz and Freund, 1951: 29), and in Russia where it has been noted at Kostienki I, Malta, Kostienki IV, Berdis and other sites (Golomshtok, 1938).
9. *Blades with prepared striking platform* 2 specimens. These are rather squat, flat blades with prepared striking platforms of Levalloisian type.
10. *Trimming blades*—26 specimens. These tools are triangular in cross-section with one of the upper faces showing the characteristic flaking that is part of the preparation of the core (fig. 9: 60).
11. *Pseudo-endscrapers*—12 specimens. One of the most surprising aspects of the *Libri Schmidt* assemblage is the absence of true endscrapers on blades. The specimens listed here qualify as endscrapers only in as much as their working edge is terminal to the blade. Most specimens are straight-ended with nibbled terminal retouch or, in two cases, exceedingly rudimentary rounded scraping ends (fig. 5: 15, 16, 18; fig. 9: 58). In one case the scraping end constitutes a terminally slightly notched edge (fig. 5: 14), in another the working end is narrowed through bilateral shouldering (fig. 5: 13).

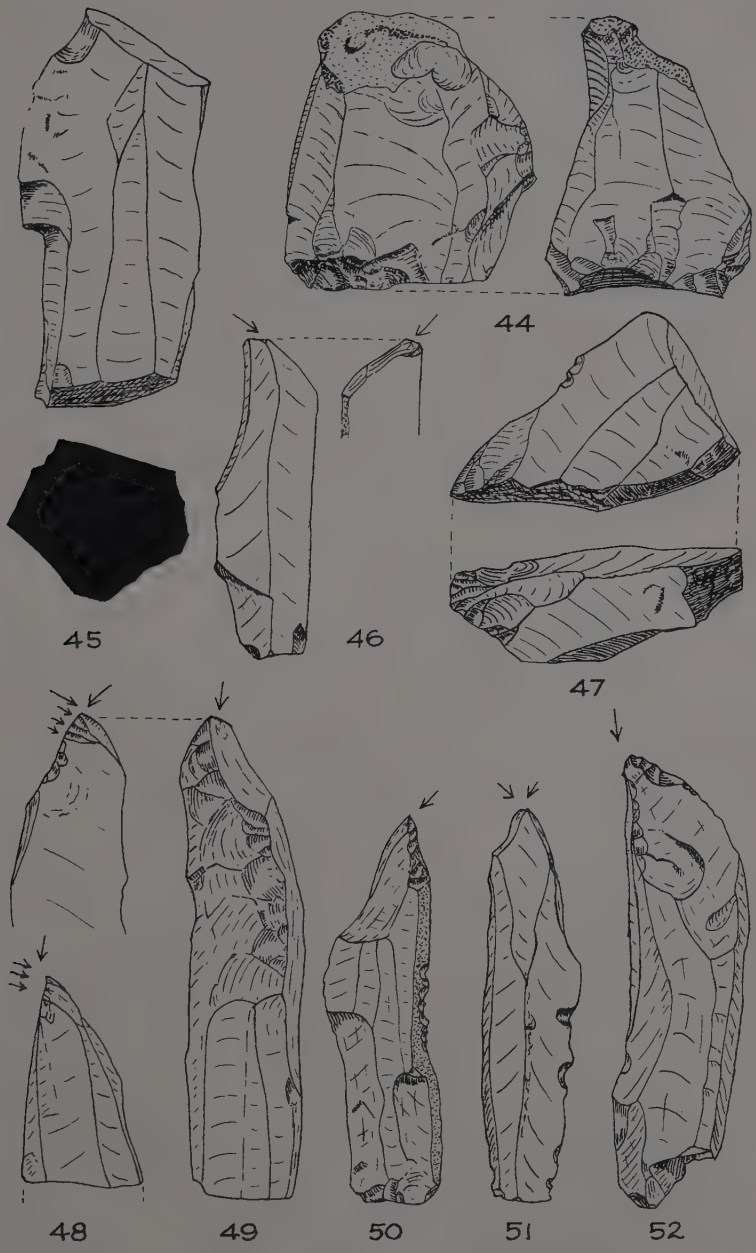

FIGURE 7. Artifacts from the *Abri Schmidt*.

FIGURE 8. Artifacts from the *Abri Schmidt*.

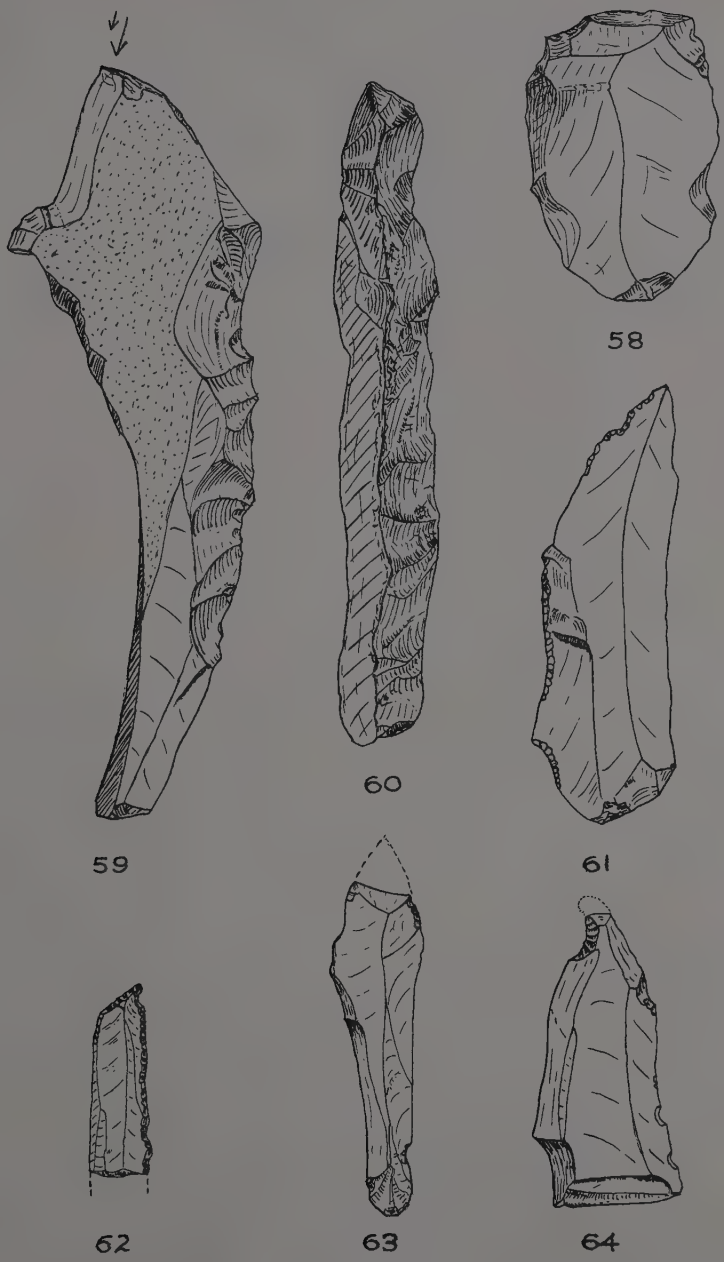

FIGURE 9. Artifacts from the *Abri Schmidt*.

12. *Zinkens*—2 specimens. Both specimens conform to the types defined for the late Palaeolithic industries such as the Hamburgian of northern Europe (fig. 9: 62, 64).
13. *Borers*—2 specimens. These are blades which are terminally obliquely notched, one of the corners being worked into a borer point (fig. 4: 7, 11).
14. *Atypical single-shouldered points*—6 specimens. This category includes two specimens with well-worked tangs in the backed-blade tradition (fig. 5: 35, 36). In all cases the tangs have been deliberately prepared by retouch flaking and "shouldering." In all determinable cases, except one, the functional end has been especially retouched (fig. 4: 5, 6; fig. 9: 63). These tools are well within the range of the shouldered points of the Russian late "Aurignacian," notably Kostienki (Golomshtok, 1938; Zotz, 1951). The two small points (fig. 5: 35, 36) have parallels in the Lower Austrian Loess Palaeolithic.
15. *Burins*—46 specimens. The Burins, short of plain blades, are the most common types of tools in the entire assemblage. They can be analyzed as follows:
    A. Burins on blades: 31 (fig. 7: 46, 48–52; fig. 8: 54, 55).
        (1) Angle Burins: 6
        (2) Burins on angles of blades: 22
        (3) Becs de flute: 3
    B. Burins on flakes: 2 (fig. 8: 53)
        (1) Burins on angles of flakes: 2
    C. Burins on cores: 13 (fig. 8: 56–57; fig. 9: 59).
        (1) Angle burins: 2
        (2) Burins on angles of cores or core fragments: 7
        (3) Becs de flute: 4
        (4) Double-ended burins: 2

    Though usually core burins are rather shapeless, this does not hold true for the present series. Many of the tools are on long regular blade-like pieces of tabular flint. Thus, these usually massive artifacts reflect the nature of the raw material (fig. 8: 56, 57; fig. 9: 59).
16. *Cores*—15 specimens. These are all Upper Palaeolithic blade cores. They include tabular, cylindrical, and pyramidal forms. Some of the pyramidal cores show signs of having been used as planers (fig. 7: 44–45).
17. *Nose scrapers*—2 specimens. These tools are made on massive core fragments with the characteristic steep nose jutting out from the flat plane of the tool (fig. 7: 47).
18. *Side scrapers on cores*—2 specimens. These elongated, steep tools show careful lateral flaking along one side, suggesting that they were used as side scrapers (fig. 4: 3).
19. *Bifacial axe tool*—1 specimen. This fragmentary tabular implement, roughly rectangular in shape, is terminally flaked on both faces, so as to create a core-axe-like effect. The original length of the specimen may have been about 8 cm.
20. *Plain débitage*—704 specimens. This series consists of flakes and flint fragments that are unretouched and, apparently, unutilized. They are the biproduct of tool-making. Many specimens are elongated and tabular slabs of flint reflecting the nature of the raw material.
21. *Retouched or utilized débitage*—76 specimens. This series consists of plain flakes or rejects showing intentional retouch flaking or signs of having been utilized. The retouch flaking is always of the nibbled variety. Rarely is it extensive; often it is in the shape of notches.
22. *Burin spalls*—19 specimens.

Table 1 illustrates the size distribution of the *Abri Schmidt* industry.

THE BONE INDUSTRY

Only three bone tools were found at the *Abri Schmidt*. One of these is very significant. This artifact is a large spoon or spatula-shaped object of mammoth tusk ivory; in its fragmentary state it is about 40 cm long. Nearly identical objects were found at such eastern sites as Unterwisternitz, Pollau and Predmost (Zotz, 1951: 214). The other worked bone tools consist of a rather shapeless bone spatula, 18 cm in length, and of a fragment of cut ivory.

TABLE 1

The size distribution of the Abri Schmidt *industry*

Dimensions in 2-cm groups	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	Totals
Artifacts	22	229	213	109	33	5	4	1	616
Débitage	278	316	110	16	3	—	—	—	723
Totals	300	545	323	125	36	5	4	1	1339

THE FAUNA

The analysis of the faunistic remains from the culture layer of the *Abri Schmidt* was carried out by D. C. Roberts, Associate Curator of Paleontology at the Cleveland Museum of Natural History. The report states that unfortunately ". . . the humans who inhabited the cave left for posterity a poor assemblage of teeth and fragmentary bones, which make positive identification as to species and even genus impossible in many cases." The following is a list of identifiable material:

Lepus timidus, common hare (at least three individuals)
- 2 partial lower jaws
- 3 partial scapulae
- 1 distal end humerus
- 5 proximal ends radii
- 5 metacarpals
- 3 partial pelves
- 1 proximal end femur
- 1 proximal end tibia
- 2 partial ribs
- 1 metatarsal

cf. *Alopex* sp., Arctic Fox
- Most of body of lower jaw with first and second molars.

cf. *Rangifer* sp., (tarandus ?) Reindeer
- 1 partial jaw of young adult with three molars
- 2 lower milk molars
- 2 unerupted lower molars
- 1 upper molar from young individual
- 1 upper molar from adult
- 1 lower premolar
- 1 incisor
- Condyle and coronoid process of jaw (not necessarily from same individual). Artragalus and phalanx from deer family, presumably Reindeer.

cf. *Capra* sp., Ibex
- Second upper molar

Equus sp., Horse
Half of an upper second premolar
cf. *Mammuthus* sp., Mammoth
Fragment of tusk
Bird, possibly small owl
1 proximal portion humerus
1 proximal portion tibiotarsus

This faunistic assemblage, though it contains characteristic "cold" forms, would by no means be out of place in an Interstadial fauna. Hence, it does not contribute much to the dating of the site.

DISCUSSION

What is the nature of the *Abri Schmidt* industry? Late eastern Aurignacian elements are represented in the form of several types such as atypical single-shouldered points, and blades with shallow terminal ventral retouch similar to Predmost, Kostienki, etc. Less well differentiated, geographically, but clearly Late Aurignacian in time, are the numerous burins and slender plain blades, the broad pointed blades with bilateral heavy marginal retouch, the nose-scrapers, the rough strangulated blade, and the backed blades. The last-named type occurs both in the tiny nibbled blade form that is known from the Magdalenian and, more commonly, in the classical "Gravette" style of eastern and western Europe alike. The backed blade with oblique terminal ventral retouch is a characteristic form of the French Gravettian (Perigordian 5). Finally, the occurrence of one of those large, typically eastern, spoon-shaped tools made on a mammoth tusk (see Zotz, 1951: 214) indicates Late Eastern Aurignacian connection.

Magdalenian elements are represented by zinkens, fine borers, certain trimming blades (though these also occur in other assemblages), and straight-ended "pseudo-endscrapers." The zinkens certainly point toward an eastern facies of the Magdalenian.

On the whole, the Late Aurignacian elements are much stronger than the Magdalenian ones at the *Abri Schmidt*. However, one should approach a decision as to the nature of the industry with caution because certain factors remain to be explained before a clear identification can be reached. The most puzzling enigma is the complete absence of true endscrapers on blades. This certainly is not an Aurignacian feature. On the other hand, neither is it characteristic of the Magdalenian. It must be remembered, however, that at least one Magdalenian station east of the Rhine, that of Linsenberg near Mainz, is characterized by an almost total absence of endscrapers (Zotz, 1951: 234).

In conclusion, the position of the *Abri Schmidt* industry can perhaps be defined as falling into the very end of the Late Eastern Aurignacian, possibly overlapping the beginning Magdalenian. The orientation of the industry, in most of its components, is clearly eastern. This is especially obvious as far as the Late Aurignacian components are concerned. They link Bavaria via the Czechoslovakian sites with Russia. Among the Magdalenian components the zinkens also point toward the East.

The chronological position of the *Abri Schmidt* may fall into a very early phase of the Würm III stadial or into the tail-end of the Würm II/III interstadial. A very late Aurignacian date would *prima facie* be more in agreement with a late interstadial identification of the stratigraphic record.

The fauna is somewhat nondescript and scanty, but it includes forms which, though "cold," are certainly not uncommon in the interstadial deposits.

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Historical Geology. *Carl O. Dunbar.* John Wiley & Sons, Inc., New York. Second edition, 1960. xi+500 pp. $7.95.

This most recent addition to a famous series of textbooks retains the pattern and advantages of its predecessors. Consequently it will be regarded with favor by those who have used and admired the earlier works; teachers who have been waiting for a new departure in textbooks of historical geology—say a regional approach—will be disappointed. The organization, of chapters and within chapters, of the new edition is almost identical to that of the first. A number of changes of detail have been made—mostly addition of new information and conclusions and revisions of historical interpretations. The chapter on cosmic history, especially, has been improved. Most of the illustrations from the earlier edition have been enlarged and used in the new one. (The publishers have adopted the wide-page double-column format.) A number of illustrations have been added. All illustrations are much more attractive than those in the older work. The paleogeographic maps have lost their clouds, some have been modified, and others have been omitted. Unfortunately the book suffers from a rash of typographical errors in the tables and picture captions, but these doubtless will be removed in later printings.

MALCOLM P. WEISS

Mineral Equilibria at Low Temperature and Pressure. *Robert M. Garrels.* Harper & Brothers, New York. 1960. xvi+254 pp. $6.00.

A possible subtitle for this book might be: Examples of the applicability of the theory of electrolytic solutions to the formation of minerals. The author has surely taken a step in the right direction by bringing together this information in convenient and readable form.

Most unfortunately, the entire topic of silicate chemistry (precipitation, dissolution, and interaction of silicates, phosphates, etc.) has been ignored, except for one incidental example involving $FeSiO_3$. In view of the superabundance of silicate minerals and their authigenic occurrences in sediments, the only justifiable reason for the exclusion of this very important topic is the inadequacy of the data. Nevertheless, I believe that Professor Garrels might have performed a very useful service merely by emphasizing the fundamental differences which exist between the chemical kinetics of silicate and non-silicate aqueous systems.

This work represents a fifteenth title in the geoscience series of this publisher and the second authored by Professor Garrels, Harvard University.

DUNCAN MCCONNELL

A Manual of Common Beetles of Eastern North America. *Elizabeth S. Dillon and Lawrence S. Dillon.* Row, Peterson and Company, Evanston, Illinois, 1961. viii+884 pp. $9.25.

The authors intend this book for naturalists, amateur collectors, students, and professionals interested in Coleoptera. It includes beetles of eastern half of North America west to 100th meridian and south to Mexico, and is based on approximately 1200 species in 64 families.

Four color plates of adults, two outline plates showing structure, two showing types of larvae, seventy-seven plates of good assembly drawings and 544 figures illustrating characters are included.

Methods of collecting, killing, preserving, pinning and labeling are included as well as an explanation of structure and use of keys, with glossary in back.

Ecology is explained with reference to water, soil, plants and other animals.

Keys to families, tribes and more common genera and species are given, as well as descriptions of species.

The bibliography is divided into: general; ecology; baits and trapping; and arrangement by families. State and Canadian lists of insects are included as well as a listing of dealers in literature and supplies. There is also an index to species.

Most of the assembly drawings are good enough to identify families and the manual should serve a useful purpose.

J. N. KNULL

HYDROLYSIS OF UNIUNIVALENT SALTS IN AQUEOUS SOLUTIONS. I– THE HYDROLYSIS OF WEAK ACID–WEAK BASE STRONG–ELECTROLYTE SALTS†

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Introduction

Solution theory taught in beginning analytical chemistry courses has to be restricted to explanations that sophomore-level students can follow. The explanation usually given is based on Arrhenius' theory of ionization. It applies with the precision needed to the laboratory examples commonly chosen except for the case of weak acid-weak base salts. The hydrolytic constants derived for this case present an explanation that postulates equal hydrolysis for anions and cations in contradiction of the fact that it is applied to systems where the acid and base ionization constants may differ by orders of magnitude (Glasstone, 1949, 1950). It may not be generally known that this involves a violation of the Law of Conservation of Matter.

Electrical Neutrality of Electrolyte Solutions

The behavior of an electrolyte, BA, of varient degree of dissociation, for dilute solutions, can be represented by the Arrhenius' theory formulation:

$$\begin{array}{ccccc} BA & \rightleftharpoons & B^+ & + & A^- \\ & & + & & + \\ HOH & \rightleftharpoons & OH^- & + & H^+ \\ & & \downarrow\uparrow & & \downarrow\uparrow \\ & & BOH & & HA. \end{array} \qquad (1)$$

For solutions where the concentration of a solute species, e.g., c_{B^+}, can be taken as equal to its activity, e.g., a_{B^+}, the expression $[B^+]$ is employed, in units of moles per liter. Such expressions are generally limited to dilute solutes, except that where the solvent is one but slightly affected in activity by the interactions considered, they may also be used. Thus, for (1),

$$[HOH] = \text{constant} = \text{about } 55.5 \text{ moles/liter}. \qquad (2)$$

In the solution for which (1) describes the essential solute-solvent interaction, the constituents B, A, H, and OH are each present as three different species, e.g., B atoms occur in BA, B^+, and BOH. By the Law of Conservation of Matter, the concentration of the constituent B, $\{B\}$, is:

$$\{B\} = [BA] + [B^+] + [BOH]. \qquad (3)$$

Similarly,

$$\{A\} = [BA] + [A^-] + [HA], \qquad (4)$$

$$\{H\} = [HOH] + [H^+] + [HA], \qquad (5)$$

and,

$$\{OH\} = [HOH] + [OH^-] + [BOH]. \qquad (6)$$

†Presented before Section G, Ohio Academy of Science Meeting, Yellow Springs, Ohio, April 22, 1960.

Then, since the Law is holding,

$$\{HOH\}=\{H\}=\{OH\}, \tag{7}$$

and,

$$\{BA\}=\{B\}=\{A\}. \tag{8}$$

Since, by (7), it follows from (5) and (6) that:

$$[HOH]+[OH^-]+[BOH]=[HOH]+[H^+]+[HA], \tag{9}$$

then,

$$[BOH]+[OH^-]=[HA]+[H^+]. \tag{10}$$

Since, by (8), it follows from (3) and (4) that:

$$[BA]+[A^-]+[HA]=[BA]+[B^+]+[BOH], \tag{11}$$

then,

$$[HA]+[A^-]=[BOH]+[B^+]. \tag{12}$$

Adding (10) and (12),

$$[BOH]+[HA]+[OH^-]+[A^-]=[BOH]+[HA]+[H^+]+[B^+]. \tag{13}$$

Cancellation in (13) gives:

$$[OH^-]+[A^-]=[H^+]+[B^+]. \tag{14}$$

Assuming that electrons obey the Law of Conservation of Mass, and that their charge is unitary, (14) expresses what has been postulated as an independent Law of Electrical Neutrality of Electrolyte Solutions (Griffith, 1921–2).

Violation of the Electrical Neutrality Law

For the hydrolysis of a strong salt of a weak acid, HA, and a weak base, BOH, (1) is usually written:

$$\begin{array}{ccccc} BA & \rightleftharpoons & B^+ & + & A^- \\ & & + & & + \\ HOH & \rightleftharpoons & OH^- & + & H^+ \\ & & \downarrow\uparrow & & \downarrow\uparrow \\ & & BOH & & HA. \end{array} \tag{15}$$

For a strong electrolyte, in dilute solution, for any $\{BA\}$,

$$[BA]=O. \tag{16}$$

Because of (2), it is possible to express the ionization constant of water as:

$$[H^+]\,[OH^-]=K_w=1 \times 10^{-14}. \tag{17}$$

The net hydrolytic reaction indicated in (15) can be expressed by the summation,

$$B^+ + A^- + HOH \rightleftharpoons BOH + HA, \tag{18}$$

which assumes that both ions can be correlated despite the fact that each actually reacts with water separately.

For the reaction assumed in (18), the reaction constant, taken to be the actual hydrolysis constant $K_{h_{BA}}$, is expressed as:

$$K_{h_{BA}} = [BOH]\,[HA]/[B^+]\,[A^-], \tag{19}$$

with [HOH] eliminated as a separate term by using (2) as in (17). Since multiplying the denominator and numerator of (19) by the quantity $[H^+]\,[OH^-]$ would leave its value unchanged,

$$K_{h_{BA}} = ([BOH]/[B^+]\,[OH^-])\;([HA]/[H^+]\,[A^-])\;([H^+]\,[OH^-]), \tag{20}$$

and

$$K_{h_{BA}} = K_w/K_{BOH}K_{HA}, \tag{21}$$

where K_{BOH} is the ionization constant of the weak base as usually defined,

$$K_{BOH} = [B^+]\,[OH^-]/[BOH], \tag{22}$$

where K_{HA} is the ionization constant of the weak acid as usually defined,

$$K_{HA} = [H^+]\,[A^-]/[HA], \tag{23}$$

and K_w is as defined in (17).

It can be shown that use of the expression (21), commonly employed in college teaching, by virtue of the inadequacy of (18), leads to a general violation of the electric neutrality rule and of the basic laws underlying it, for the general condition,

$$K_{HA} \neq K_{BOH}. \tag{24}$$

A general expression for this inequality could be readily derived, but it is more complicated than would be desired for sophomore instruction (Griffith, 1921–2). Demonstrating the inequality by a selected example is more simple and has the advantage of providing a starting point for the rapid calculation of an instructive correction.

Alpha-naphthylaminium barbiturate seems an apt choice for a sample calculation. For alpha-naphthylamine:

$$K_{BOH} = K_b = 9.9 \times 10^{-11} \cong 1 \times 10^{-10}, \tag{25}$$

and for barbituric acid,

$$K_{HA} = K_a = 1.05 \times 10^{-4} \cong 1 \times 10^{-4}. \tag{26}$$

Assuming a solution 0.001 M in this salt, by (21),

$$K_{h_{BA}} = 1, \tag{27}$$

and, by (19),

$$[A^-] = [B^+] = [BOH] = [HA] = 0.0005 \text{ M}. \tag{28}$$

This result follows from the usual calculations used in solution problems. However, from (23),

$$[H^+] = 0.001 \text{ M}, \tag{29}$$

and from (22), or via (17),

$$[OH^-] = 10^{-10} \text{ M}, \tag{30}$$

on using the values of (28). Thus, there is an excess of 0.0001 mole of positive charge per liter of solution, a fantastic discrepancy.

Minimization of Electrical Neutrality Violation

There are two approaches to avoiding the discrepancies that arise for the general case (24) when (21) is used. One approach is to replace (18) by an expression in which the separate hydrolysis of B^+ and of A^- is taken account of in the correlation; this leads to quadratic equations that are simple algebraically, accurate in principle, but require manipulations too complicated arithmetically for slide-rule manipulation or for average sophomore performance (personal communication, Dr. P. M. Williamson). The other approach is that of correcting the discrepancy by a numerical minimization technique. This technique could be expressed generally in the form of a single recursive series formula. (General iterative functions applicable to computer programming have been derived, and will be reported elsewhere). Again, using an example, that already taken, offers a simpler means of indicating the actual technique.

From (28–30)

$$[B^+]+[H^+]=[A^-]+[OH^-]+0.0001. \tag{31}$$

If one-half of the excess positive charge is equally distributed by adding half of it to $[A^-]$ and subtracting half of it from $[B^+]$, then, by (19),

$$[B^+]=[HA]=0.00045 \text{ M}, \tag{32}$$

and,

$$[A^-]=[BOH]=0.00055 \text{ M}. \tag{33}$$

The same results could be derived by use of (12) and its antecedents. By (23), for these first corrected values (32) and (33),

$$[H^+]=8.18 \times 10^{-5} \text{ M} \quad ([OH^-]=1.22 \times 10^{-10} \text{ M}). \tag{34}$$

From (28–30),

$$[B^+]+[H^+]=[A^-]+[OH^-]=0.0000182. \tag{35}$$

TABLE 1

Hydrolysis of 0.001 M BA, $K_a=10^{-4}$, $K_b=10^{-10}$, strong salt tabulation of effect of corrections for electrical neutrality violation

Quantity	Uncorrected	First Cycle Correction	Second Cycle	Third Cycle
$[HA]=[B^+]$	0.0005	0.00045	0.000459	0.0004576
$[BOH]=[A^-]$	0.0005	0.00055	0.000541	0.0005424
$[H^+] \times 10^{+4}$	1.	0.818	0.848	0.845
$[OH^-] \times 10^{+10}$	1.	1.22	1.18	1.19
Charge Discrepancy*	$+1 \times 10^{-4}$	-1.82×10^{-5}	$+2.8 \times 10^{-6}$	-3×10^{-7}

*In units of 6.0268×10^{23} electron charges.

The discrepancy of (31) has been reduced about fivefold, and it has been changed in sign. The cycle (32–35) can be repeated, with due regard for alternation of signs, to reduce the discrepancy to as small an amount as may be desired. Table 1 shows the progress made by further pursuit of such calculation.

Summary

It has been shown that for the case of weak acid-weak base strong salts, where the ionization constants of the acid and base involved differ appreciably, the hydrolysis constant usually derived from simple Arrhenius' theory gives an inadequate and contradictory description of the solutes in dilute solution. The rule that electrolyte solutions are electrically neutral can be derived from the Law of Conservation of Matter, and can be applied to simple arithmetic recursive correction of the usual description to produce corrections of a desired order of accuracy. Its application is sufficiently simple and rapid, and the concepts involved are fundamental enough that it can be applied to elementary teaching.

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